Summer 1982

Hospital Short Term Planning Through Patient Census Forecast

Wenhao Chiu
University of Central Florida

HOSPITAL SHORT TERM PLANNING THROUGH PATIENT CENSUS FORECAST

BY

WENHAO CHIU
B.S., Tunghai University, 1975

RESEARCH REPORT

Submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Graduate Studies Program of the College of Engineering
University of Central Florida
Orlando, Florida

Summer Term
1982

ABSTRACT

An adequate health care resource allocation in a hospital is directly dependent upon the ability to estimate the hospital's patient census accurately. Efforts to estimate hospital's patient census are classified into two general methods: estimating from historical data, and demographic analysis. This paper takes the position that the estimate from the historical data is more economic and convenient for understanding than the estimate from the demographic analysis. Seven models that predict hospital's patient census by using the hospital's historical data are evaluated to fit the characteristics of each pattern shown in historical information. Where a microcomputer is available, this forecasting system provides detailed prediction of patient census with the comparable percentage of forecasting error among each model. Data from a ten-unit hospital in Florida is analyzed and provides a predicted patient census for the hospital's short-term plan. Results of this patient census estimating system and its advantage over the other forecasting method are discussed.

TABLE OF CONTENTS

CHAPTER I

STATEMENT OF THE PROBLEM

In many hospitals the utilization of the health care resource is very inefficient because of uncertainties about the demand of future health care services. These demands which need to be considered are typically as follows (1):

1. How many beds will be required in the future?

2. What future workload will be scheduled in the diagnostic and treatment services?

3. What are the requirements of medical specialists and staff in the short and long term plan?

4. Is the present ambulatory service sufficient to handle the future demand by patient?

5. What is the best design of site use and department location in order to provide an efficient service? How many additional spaces should be reserved for the future?

6. What are the projected capital costs for providing the required program, services, and facilities?

7. What is the present market share for the hospital's service? What changes can be anticipated in this market share and what steps should be taken to maintain or enhance this share during the next few year periods?

The effective operation of the hospital is largely dependent on the accuracy of the forecast technique used to estimate the expected demand. One of the bases for the forecast of this demand is the patient census. The patient census, such as patient-days per month and admissions per day, records and provides the basic information about the activities of the hospital in the past and present time. Under the same environment and situation, the future role of the hospital in providing the health care service can be predicted.

Minimizing the forecasting error is the main objective in predicting future patient census. However, for a more accurate forecasting patient census, a higher cost will have to be incurred. The optimal level of the forecasting effort is the level which minimizes the total cost of forecasting and losses due to uncertainty. In other words, it determines which forecasting method should be properly selected. The selection of the appropriate forecasting method is influenced by the following factors (2):

1. Form of forecast required.
2. Forecast horizon, period, and interval.
3. Data available.
4. Accuracy required.
5. Behavior of process being forecast (demand pattern).
6. Cost of development, installation, and operation.
7. Ease of operation.
8. Management comprehension and cooperation.

The primary objective of this research is to predict the future demand of hospital health care service by a set of mathematical forecasting models. The forecasting process is also subject to the following considerations.

1. The optimal forecasting level should be under the balance of forecasting costs and losses due to forecasting accuracy.

2. The quantitative data analysis uses information which is currently, routinely gathered in the hospital.

Under these considerations, different mathematical models are introduced and compared in order to fit the best forecasting model to the demands of each health care service.

CHAPTER II

LITERATURE SEARCH

In order to provide an accurate forecast of patient census, many papers and models have been presented. These models are classified into two categories - Time Series, and Causal.

The time series model is the quantitative data analysis which utilizes trends and seasonality-related characteristics in order to anticipate future needs. It is relatively simple in structure and economic in data collection. The data is readily available in the current routine data record, such as census or financial accounting. An appropriate model usually is suggested according to the analysis of historical record. Furthermore, an error test identifies the reliability of forecasting in using that model. The Time Series method usually provides reliable forecasting results if the sample period is large and the variables in that period are stable.

A model of the Time Series type has been proposed by Kwon, Eickenhorst and Adams (3), who use the number of daily bed reservations as a predictor of daily patient census. This model is basically a first-order linear regression using the indicated predictor as an independent variable. O'Connor and Efurd (4) predict patient census, staffing needs and costs using a first-order linear regression model with smoothing factors by day of the week. They use bed reservations (times a multiplier, i.e., the ratio of reservations to admissions per each day of the week) to forecast. Both of these papers found that there existed unusual deviation (out of the $\pm$ 1.5 standard deviation) between the actual and predicted patient census on some particular days. They supposed that it was due to a holiday or seasonal effect. In order to get an accurate regressional formula, those unusual days could be eliminated from the sample data.

Wood (5) developed a one-day ahead prediction model of total patient census using today's census and the census 8 days and 7 days prior to today, along with an indicator of the "seasonality" attributable to the day of the week. He reports approximately 2% absolute error for the one-day-ahead forecast and up to 10% error for the four-week-ahead forecast.

Harris and Adam (6) describe the development of five short-term forecasting models (simple monthly average; simple, double, and adaptive exponential smoothing, and a moving-average regression method) to predict the daily patient tray demand in a hospital. All models were more accurate than the intuitive forecast made by the food service supervisor.

Swain, Kilpatrick and Marsh (7) implemented at two hospitals an on-line model for daily forecast of admission for 22 separate medical and surgical services. Accuracy varied by service and number of days ahead predicted. The model computes, daily, the number of elective admissions that will maximize the census over the short run, subject to constraints on the probability of overflow.

The use of the causal forecasting model involves the identification of independent variables that are related to the dependent variable to be predicted. Once these related independent variables have been identified, a statistical model that describes the relationship between these independent variables and the dependent variable to be forecasted is developed. The statistical relationship derived is then used to forecast the dependent variable of interest.

TriBrook Group Inc. (1), a hospital consulting company, provided the Jess Parrish Memorial Hospital a long term plan through forecasting patient census with the causal model. This model was developed from the following four steps:

1. Identify the hospital's primary and secondary service area. Make a forecast regarding where hospital service areas are likely to be in the future and what steps may be required to maintain or enhance the hospital's market share.

2. Review demographic characteristics of the hospital's service area and develop a profile of patients using the hospital. This includes such factors as past population change, age distribution, income, racial distribution, birth rate, and leading cause of death, etc.

3. Review utilization of hospital health care services for past inpatient. Find the demographic or economic factors which will

increase or decrease the utilization of the health care service. Then perform regression analysis or one of the other appropriate methodologies to determine trends applicable to future utilization.

4. Determine future hospital patient service requirements. Quantitatively determine the future patient census based on projected population growth, projected utilization trend, anticipated change in market share, plans for other area hospitals, and change in hospital's mission, goals and objectives.

Gutkin (8) used a multiple regression model to predict hospital outpatient visits. Independent variable in the model were population size, full-time equivalents of house staff, number of physicians in region who were not on the hospital staff, and the number of admissions.

Another similar multivariate regression equation was also used by More and Bock (9) to estimate demand. Variables reflected demographic, economic and social factors, and existing health resources of the population. The transition of points between level of care, recovery, and death are processed by age group.

Gurtfield (10) developed a set of interrelated models for long-term strategic planning: the first one forecasted expected utilization; the second related demand to resource requirements (physicians, beds, operating rooms, laboratories, etc.) and the others combined both models to create a scenario for the late 1980's.

The causal or qualitative method, such as the forecasting through demographic analysis, might be used in the patient census forecasting. The reason that Time Series Method is used instead of the Demographic Analysis Method could be stated as follows:

1. Time series data could be easily and inexpensively obtained. The data to be used is routinely gathered by the accounting or administrative department for financial and management purpose. On the contrary, the demographic data is beyond the hospital internal record gathering system and even very scarce in the records of certain government departments. Some private companies could provide such kind of service but they charge a lot of money for that and the accuracy of this information is still uncertain.

2. The models used in Time Series Method are simple in structure and easy to be understood and operated. However, the user of demographic approach might spend more time in the understanding of complicated characteristics of demography, such as population change, age distribution, income, racial distribution, etc.

3. When a new value is available, the time series model only has to keep track of the value forecasted one period ago and update the mathematical formula used in this model. However, to update the information relative to the demographic approach is not a easy job. It takes time to revise the new demographic charasteristics

and develop a new relationship between the independent and dependent variable.

CHAPTER III

METHOD OF APPROACH

3.1 Introduction

There are many forecasting techniques which were built and developed according to the analysis of the characteristics of the items to be forecasted. Bowerman & O'Connell (11) divided these techniques into two basic types-qualitative method and quantitative method. The qualitative methods are used when the historical data is not available or is scarce and dependent on the opinions of experts who subjectively predict future events. The quantitative forecasting techniques are used when the historical data is available. The Time Series Model will predict the future value of a variable on the basis of the historical pattern of that variable. It is common to use both qualitative and quantitative methods to forecast the future value in actual practice.

Since the historical data is already available in the hospital's routine data collection, the forecasting technique that will be used in this research is the quantitative method. In developing the suitable model for the forecast of patient census, the pattern of the past data will be considered.

A forecasting model using the Time Series Method assumes that some patterns or relationships exist that can be identified and used as the basis for preparing a forecast. When the historical data is plotted on a graph, it can be classified into four kinds of patterns shown in Figure 1. Figure 1.1 is the horizonal pattern which shows that the past data fluctuated around the mean with a stationary pattern. Some data may show a trend over several years but is stationary for short term forecasting. Figure 1.2 is the seasonal pattern which indicates that the past data fluctuated according to a seasonal factor. An obvious example is the occurrence of sunstrokes and drowning cases which present a high volume in summer and low volume in winter. Figure 1.3 is the trend pattern which shows a general increase (or decrease) in the value of a variable over time. Figure 1.4 shows the cyclical pattern which is similar to a seasonal pattern, except that the length of a single cycle is generally longer than one year. In Time Series, these four patterns can often be found in combinations as well as each by itself. Several characteristics of time series patterns are discussed in Appendix A.

3.2 Model Development

To forecast time series, it is necessary to represent the behavior of the historical data by a mathematical model that can be extended into the future. It is required that the model be a good representation of the observation which is close to the present time. Once the valid model for the time series has been established, an appropriate forecasting technique can be developed.

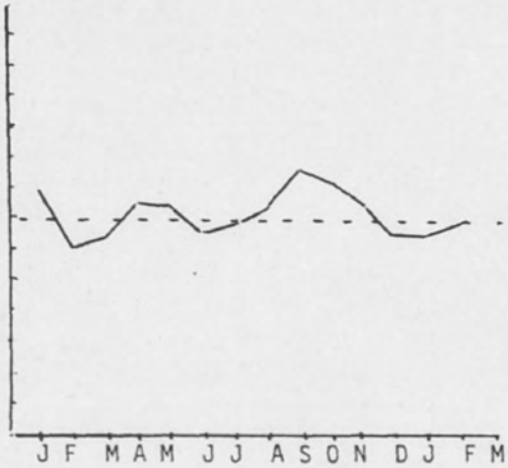


Figure 1.1. Horizontal pattern.

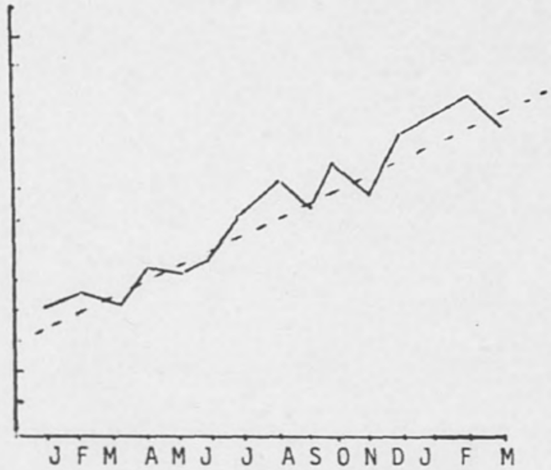


Figure 1.3. Trend pattern.

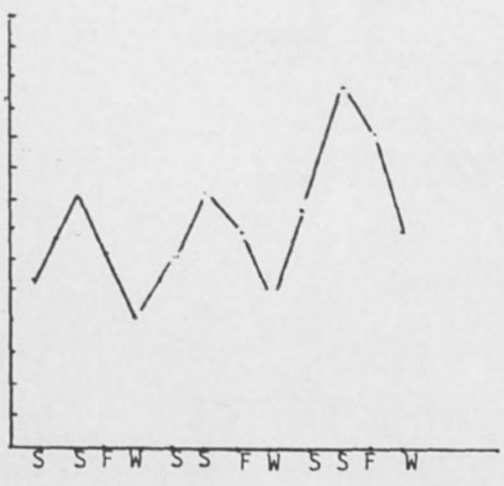


Figure 1.2. Seasonal pattern.

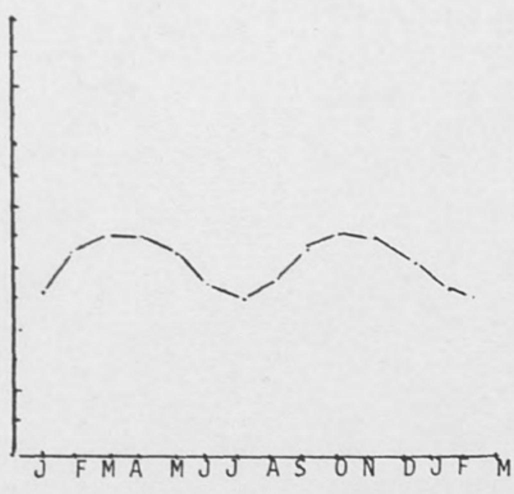


Figure 1.4. Cyclical pattern.

Figure 1. Patterns of time series data,

Many models are developed with the use of algebraic or transcendental functions of time. In this hospital's short-term plan through patient census forecasting, the following models will be considered and used:

1. Linear Regression.
2. Simple Moving Average.
3. Double Moving Average.
4. Simple Exponential Smoothing.
5. Double Exponential Smoothing.
6. Additive Seasonal Smoothing.
7. Multiplicative Seasonal Smoothing.

Simple Moving Average and Simple Exponential Smoothing Models suppose that there exist no characterisitics of trend and seasonality in the analysis of historical data. However, Linear Regression, Double Moving Average, and Double Exponential Smoothing models have the characterisitics of trend but without seasonality. If both the trend and seasonal characteristics exist in the analysis of historical data, Additive Seasonal Smoothing and Multiplicative Seasonal Smoothing Models will be suggested to use. The detailed mathematical discussions of the above models are described in Appendix B.

All forecasting situations involve some degree of uncertainty. The presence of this irregular component, which presents unexplained or unpredictable fluctuations in the historical data, means that some error in forecasting must be expected. The accuracy of a forecasting method is determined by analyzing forecast errors already experienced. If the forecasting errors over time indicated that the forecasting methodology is appropriate (random distribution of errors), it is important to measure the magnitude of the errors so that we can determine whether accurate forecasting is possible. In order to do this, one might use the following error measurement methods:

1. Mean Square Error (MSE).
2. Mean Absolute Percentage Error (MAPE).
3. Mean Absolute Deviation (MAD).

The mathematical definition of the above error measurements are described in Appendix C. The basic difference between MAD and MSE is that MSE, unlike the MAD, penalizes a forecasting technique much more for large errors than for small errors. For example, an error of 2 produces a square error of 4 while a error of 4 (an error twice as large) produces a square error of 16 (a square error four times as large). Because MAPE is expressed on a percentage basis, it is a convenient way to compare the errors produced by different forecasting techniques. The starting forecasting model to be considered is the method that produces the smallest mean absolute percentage error (MAPE).

During the process of measuring the forecasting error the model also has to pass the Moving Range Test. The Moving Range is defined as the absolute difference of the errors observed in two successive periods. The chart is drawn around the average value of these difference. The objective of the control chart is to detect the pressence of outliers and/or of trends (several value in a row larger (or smaller) than the average)). The definition and control principle of Moving Range are described in Appendix 4. If the out-of-control condition appears in the Moving Range Test, the model should be modified in order to better represent the time series process. This can be done by changing some parameter(s) in this model or chosing another model which will reduce MAPE and pass the Moving Range Test.

3.3 Forecasting Technique

It is convenient to think of the two primary functions of a forecasting system as forecast generation and forecast control. Forecast generation involves the following activities (12):

1. Develop a demand theory which will clearly represent the relevant variable and functional forms in this forecasting system.

2. Collect, verify, and prepare data.

3. Use the data to revise the forecast model. Three steps should be taken.

   a. Select a model.
   b. Select initial value of parameters.
   c. Verify fit by using the bulk of the data to estimate model performance and using the rest of the data as a standard to verify accuracy.

4. Produce a forecast with selected model.

5. Present the forecast to management.

Forecast control involves monitoring the forecasting process to detect out-of-control conditions and identify opportunities for improving forecasting performance. It involves the following activities:

1. Update forecasts as new data is gathered.

2. Monitor accuracy and stability of forecast.

3. Take action by changing parameters or model if there is a significant difference between the forecasted and actual value.

Several feedback actions should encourage improvement of the model to be used in this forecasting system. A conceptual relationship among those activities is shown in Figure 2.

3.4 Computer Program of the Research

In this computer analysis of patient census forecasting, a microcomputer, Radio Shack TRS-80 Model III, was used. COFORAN, a forecasting package, developed at University of Central Florida by Tim Atkins, Jose Sutera, and Jose Sepulveda, was also available. The package is user-friendly. The user only has to input the historical data. The procedure to choose the best model to predict the future patient census is the following:

1. Input the number of monthly data which will be used to test each model. In this research data from the first thirty-six months out of forty months (from October 1979 to September 1981) is chosen to test seven models which have already been built into the COFORAN program.

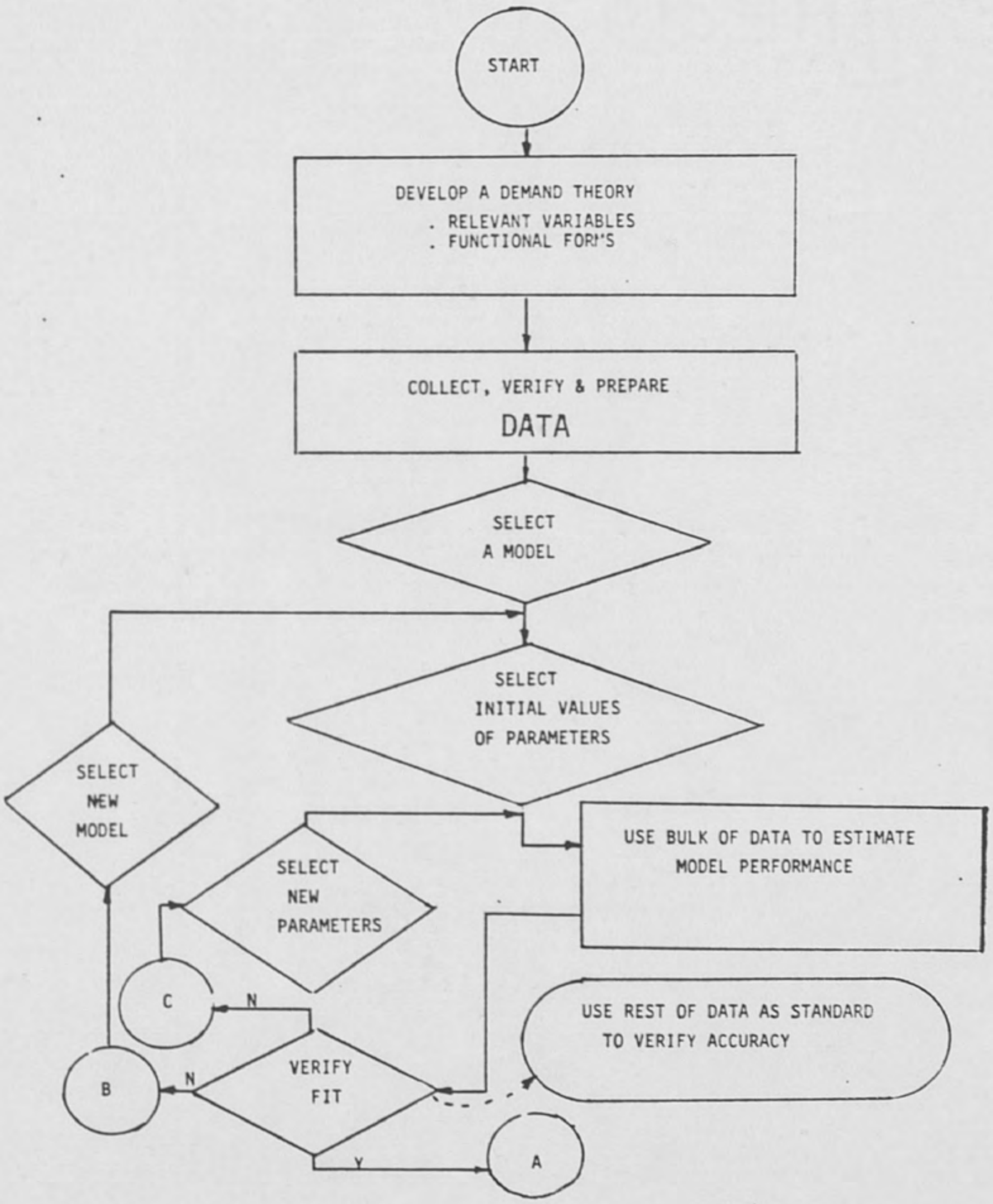


Figure 2. Selecting a forecasting technique.

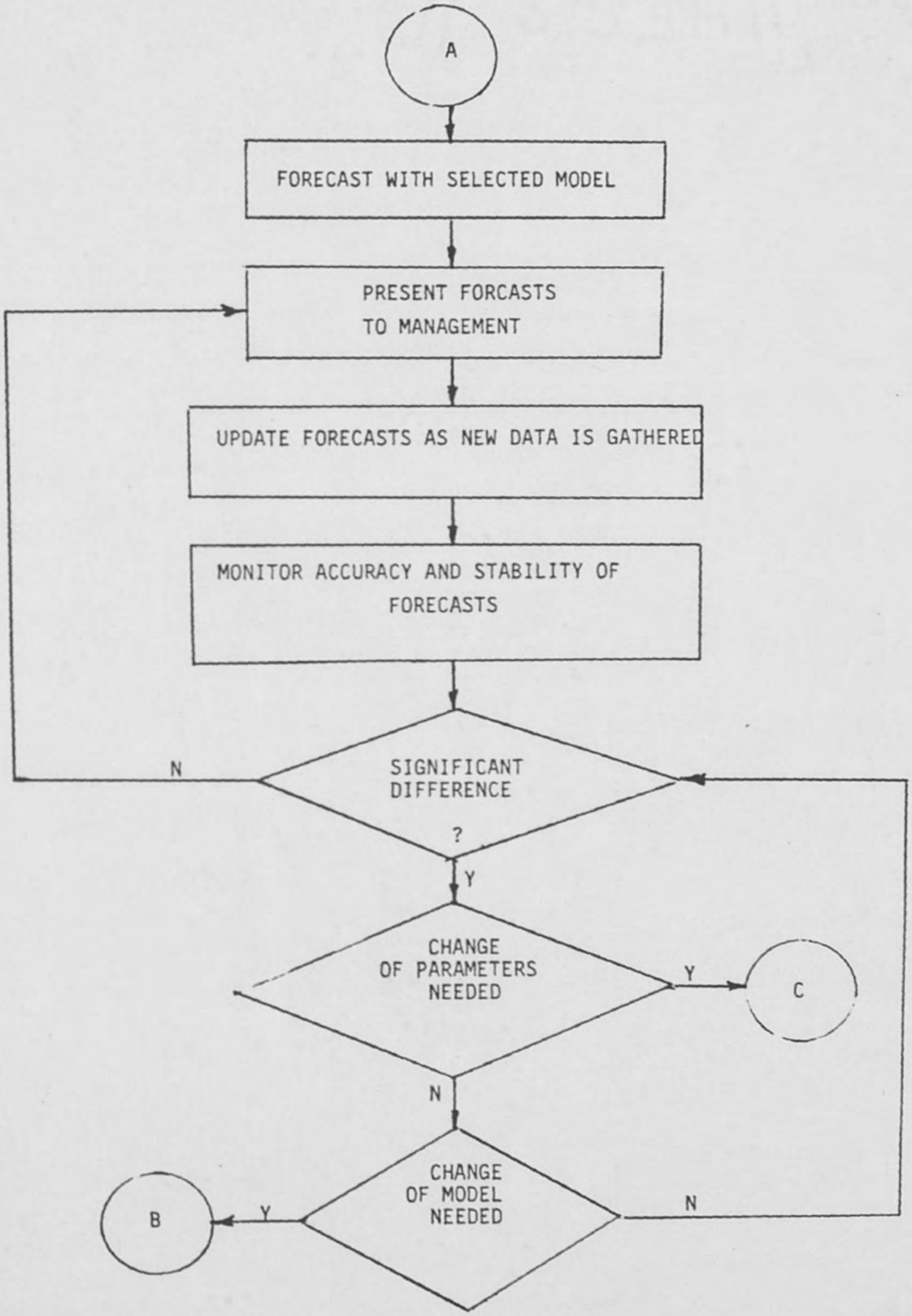


Figure 2. (Continued)

2. Give the number of months to be forecasted. Eight monthly patient census (from February 1982 to September 1982) are requested to forecast in this research because the fiscal year in this hospital starts October 1; i.e., the forty-first through the forty-eighty months.

3. Choose the model(s) to be used. This research requests the computer to test all of the seven models and print out the test model table which will come with the parameter value(s) and corresponding Mean Absolute Percentage Error (MAPE) used in each of the models. The user may select a specific model. Only if the user does not have a good feeling of how the situation is, the user asks for all models.

4. Use the data from the remaining four months to start the Moving Range Test using the model having the smallest Mean Absolute Percentage Error. If it failed in the Moving Range Test (i.e., the forecasted data for the remaining four months was under the out-of-control condition), some actions must be taken with either changing parameter(s) of this model or choosing another model.

CHAPTER IV

RESULT AND DISCUSSION

The future patient census of each hospital unit is computed through the COFORAN program in Radio Shack TRS-80 Model III system. The output from the computer, showing the process of forecast for each hospital unit, is exhibited in Tables 1-13. Each output contains:

1. Suggested test table: This table demonstrates seven different suggested test models based on the first thirty-six months of historical data. It also provides the parameters and Mean Absolute Percentage Error used in each model.

2. Selected model: This model is associated with the appropriately assigned parameter in order to obtain the minimal Mean Absolute Percentage Error.

3. Moving Range Test Table: This table provides the statistical meaning of the forecasting error when the last four periods of data are used as model fitness test.

4. Forecasting Table: This table is based on the selected model.

For example in the medical unit (see Table 1), the suggested test table printed out from the computer provides seven models with the corresponding parameters and MAPE. The reason why the Double Exponential Smoothing model was chosen instead of choosing Double

TABLE 1

FORECAST MEDICAL UNIT

```
    MODEL                                              PARAMETER    MEAN ABS
                                                                    PCT ERROR
-------------------------------------------------------------------------------
 1 . LINEAR REGRESSION                              INTERCEPT=2014      8.5%
                                                       SLOPE= 1.09
 2 . SIMPLE MOVING AVERAGE                               N=  5          3.9%
 3 . DOUBLE MOVING AVERAGE                               N=  5          3.2%
 4 . SIMPLE EXPONENTIAL SMOOTHING                    ALPHA=0.30         4.0%
 5 . DOUBLE EXPONENTIAL SMOOTHING                    ALPHA=0.30         3.6%
 6 . ADDITIVE SEASONAL SMOOTHING                     ALPHA=0.20         5.4%
                                              BETA= .1   GAMMA= .05
 7 . MULTIPLICATIVE SEASONAL SMOOTHING               ALPHA=0.20         2.4%
                                              BETA= .1   GAMMA= .05


  (STATISTICS BASED ON FIRST  36 MONTHS)   ENTER SELECTION #? 5.
    D O U B L E   E X P O N E N T I A L   S M O O T H I N G
    ============================================================
ENTER THE SMOOTHING CONSTANT 'ALPHA' (0-1)? 0.18
  MONTH              ACTUAL              FORECAST              ERROR
   37                 1955                 1932                  3
   38                 1857                 1923                -66
   39                 1823                 1889                -66
   40                 1974                 1853                121
------------------------------------------------------------------------
                    I  S T A T I S T I C S  I
                    .........................
MEAN ABS. DEVIATION =    64.0     MEAN ABS. PCT. ERROR =    3.4%

WANT THE MOVING RANGE TEST? Y.


                         .................

    -170.9  -113.9   -57.0       0     57.0    113.9   170.9
    (LCL)-----------------------------------------------------(UCL)

MONTH     :       :       :       I       :       :       :
 37                               *
          :       :       :       I       :       :       :
 38                     *
          :       :       :       I       :       :       :
 39                     *
          :       :       :       I       :       :       :
 40                                               *
          :       :       :       I       :       :       :

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y.
WPCH                                              MEDICAL

                 MONTH                            FORECAST
-------------------------------------------------------------------------------
                  41    -    -    -    -    -    1869
                  42    -    -    -    -    -    1857
                  43    -    -    -    -    -    1844
                  44    -    -    -    -    -    1831
                  45    -    -    -    -    -    1819
                  46    -    -    -    -    -    1806
                  47    -    -    -    -    -    1793
                  48    -    -    -    -    -    1781
-------------------------------------------------------------------------------
  BASED ON   40   PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82
```

TABLE 2

FORECAST MEDICAL UNIT WITH MULTIPLICATIVE SEASONAL SMOOTHING MODEL

THE SEASONAL SMOOTHING MODELS USE SMOOTHING CONSTANTS (ALPHA, BETA, AND GAMMA) TO 'UPDATE' THE FORECASTS WHEN EACH NEW SALES DATA BECOMES AVAILABLE.

IT IS RECOMMENDED THAT THE VALUES OF THESE CONSTANTS BE NO LARGER THAN (0.5, 0.3, AND 0.1) RESPECTIVELY.

SELECT YOUR CONSTANTS (ENTER 0 FOR DEFAULT VALUES: .2,.1,.05)

ALPHA = ? 0.2
BETA = ? 0.1
GAMMA = ? 0.05.

M U L T I P L I C A T I V E   S E A S O N A L
S M O O T H I N G   (W I N T E R S')

MONTH	ACTUAL	FORECAST	ERROR
37	1935	1957	-22
38	1857	1722	135
39	1823	1818	5
40	1974	1954	20

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 45.5   MEAN ABS. PCT. ERROR = 2.4%

WANT THE MOVING RANGE TEST? Y

```
     -121.5   -81.0   -40.5      0     40.5    81.0   121.5
    (LCL)---------------------------------------------------(UCL)

MONTH    :       :       :       I       :       :       :
 37                          *
         :       :       :       I       :       :       :
 38                                                       >
         :       :       :       I       :       :       :
 39                              *
         :       :       :       I       :       :       :
 40                                 *
         :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? N

TABLE 3

FORECAST MEDICAL UNIT WITH DOUBLE MOVING AVERAGE MODEL

THIS MODEL REQUIRES A PARAMETER (N) WHICH IS THE NUMBER OF M
ONTHS OVER WHICH THE MOVING AVERAGE WILL BE CALCULATED.
PLEASE ENTER N (WE RECOMMEND A VALUE BETWEEN 5 AND 10)

N = ? 5.

D O U B L E   M O V I N G   A V E R A G E

MONTH	ACTUAL	FORECAST	ERROR
37	1935	1876	59
38	1857	1852	5
39	1823	1837	-14
40	1974	1803	171

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 62.3   MEAN ABS. PCT. ERROR = 3.2%

WANT THE MOVING RANGE TEST? Y.

```
    -166.2  -110.8   -55.4      0      55.4   110.8   166.2
    (LCL)---------------------------------------------------(UCL)

MONTH  :       :       :       I       :       :       :
 37                                    *
       :       :       :       I       :       :       :
 38                                    *
       :       :       :       I       :       :       :
 39                         *
       :       :       :       I       :       :       :
 40                                                     >
       :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? N

TABLE 4

FORECAST SURGICAL UNIT

MODEL	PARAMETER	MEAN ABS PCT ERROR
1 . LINEAR REGRESSION	INTERCEPT=1688 SLOPE= 2.17	9.5%
2 . SIMPLE MOVING AVERAGE	N= 5	9.4%
3 . DOUBLE MOVING AVERAGE	N= 5	12.4%
4 . SIMPLE EXPONENTIAL SMOOTHING	ALPHA=0.30	10.3%
5 . DOUBLE EXPONENTIAL SMOOTHING	ALPHA=0.30	13.1%
6 . ADDITIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	9.7%
7 . MULTIPLICATIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	10.7%

(STATISTICS BASED ON FIRST 36 MONTHS) ENTER SELECTION #? 6

SELECT YOUR CONSTANTS (ENTER 0 FOR DEFAULT VALUES: .2,.1,.05)

ALPHA = ? .03
BETA = ? .1
GAMMA = ? .05

A D D I T I V E   S E A S O N A L   S M O O T H I N G

MONTH	ACTUAL	FORECAST	ERROR
37	1817	1731	86
38	1842	1805	37
39	1378	1760	-382
40	1729	1716	13

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 129.5   MEAN ABS. PCT. ERROR = 8.6%

WANT THE MOVING RANGE TEST? Y

```
   -345.8  -230.5  -115.3      0    115.3   230.5   345.8
   (LCL)--------------------------------------------------(UCL)

MONTH    :       :       :       I       :       :       :
 37                                   *
         :       :       :       I       :       :       :
 38                                *
         :       :       :       I       :       :       :
 39      <
         :       :       :       I       :       :       :
 40                              *
         :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y

WPCH SURGICAL

MONTH						FORECAST
41	-	-	-	-	-	1812
42	-	-	-	-	-	1727
43	-	-	-	-	-	1792
44	-	-	-	-	-	1694
45	-	-	-	-	-	1709
46	-	-	-	-	-	1817
47	-	-	-	-	-	1732
48	-	-	-	-	-	1797

BASED ON 40 PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82

TABLE 5

FORECAST MEDICAL/SURGICAL UNIT

MODEL	PARAMETER	MEAN ABS PCT ERROR
1 . LINEAR REGRESSION	INTERCEPT=3705 SLOPE= 3.22	7.1%
2 . SIMPLE MOVING AVERAGE	N= 6	4.8%
3 . DOUBLE MOVING AVERAGE	N= 6	6.5%
4 . SIMPLE EXPONENTIAL SMOOTHING	ALPHA=0.15	5.0%
5 . DOUBLE EXPONENTIAL SMOOTHING	ALPHA=0.15	5.4%
6 . ADDITIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	5.6%
7 . MULTIPLICATIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	5.7%

(STATISTICS BASED ON FIRST 36 MONTHS) ENTER SELECTION #? 3.
PLEASE ENTER N (WE RECOMMEND A VALUE BETWEEN 6 AND 12)

N = ? 8

D O U B L E M O V I N G A V E R A G E

MONTH	ACTUAL	FORECAST	ERROR
37	3752	3758	-6
38	3699	3748	-49
39	3201	3657	-456
40	3703	3459	244

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 188.8 MEAN ABS. PCT. ERROR = 5.6%

WANT THE MOVING RANGE TEST? Y.

```
       -504.0  -336.0  -168.0     0    168.0   336.0   504.0
       (LCL)---------------------------------------------------(UCL)

MONTH    :       :       :       I       :       :       :
 37                              *
         :       :       :       I       :       :       :
 38                           *
         :       :       :       I       :       :       :
 39        *
         :       :       :       I       :       :       :
 40                                         *
         :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y
WPCH MED/SURG

MONTH	FORECAST
41 - - - - -	3444
42 - - - - -	3402
43 - - - - -	3361
44 - - - - -	3319
45 - - - - -	3277
46 - - - - -	3235
47 - - - - -	3193
48 - - - - -	3151

BASED ON 40 PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82

TABLE 6

FORECAST ORTHOPEDICS UNIT

```
[redacted]        MODEL                                         PARAMETER     MEAN ABS
                                                                          PCT ERROR
-------------------------------------------------------------------------------------
 1 . LINEAR REGRESSION                                  INTERCEPT= 788       4.4%
                                                          SLOPE= 5.57
 2 . SIMPLE MOVING AVERAGE                                  N=  5             7.7%
 3 . DOUBLE MOVING AVERAGE                                  N=  5             9.1%
 4 . SIMPLE EXPONENTIAL SMOOTHING                         ALPHA=0.30         6.1%
 5 . DOUBLE EXPONENTIAL SMOOTHING                         ALPHA=0.30         5.6%
 6 . ADDITIVE SEASONAL SMOOTHING                          ALPHA=0.20         4.4%
                                                   BETA= .1    GAMMA= .05
 7 . MULTIPLICATIVE SEASONAL SMOOTHING                    ALPHA=0.20         5.4%
                                                   BETA= .1    GAMMA= .05
 8 . TREND EXTRAPOLATION/SEASONAL ADJUSTMENT               P=0.20           14.4%

  (STATISTICS BASED ON FIRST  36 MONTHS)    ENTER SELECTION #? 5
     D O U B L E   E X P O N E N T I A L   S M O O T H I N G
     ===================================================
ENTER THE SMOOTHING CONSTANT 'ALPHA' (0-1)? 0.1
   MONTH               ACTUAL                FORECAST                ERROR
    37                  967                    986                    -19
    38                  960                    987                     -7
    39                  1042                   991                     51
    40                  1112                   1007                   105
 ------------------------------------------------------------------------
                        I  S T A T I S T I C S  I
                        .........................
MEAN ABS. DEVIATION =    45.5          MEAN ABS. PCT. ERROR =    4.3%

WANT THE MOVING RANGE TEST? Y.


                                 .................

     -121.5    -81.0    -40.5       0       40.5      81.0     121.5
    (LCL)-----------------------------------------------------------(UCL)

MONTH     :         :         :         I         :         :         :
 37                                 *
          :         :         :         I         :         :         :
 38                                   *
          :         :         :         I         :         :         :
 39                                                   *
          :         :         :         I         :         :         :
 40                                                             *
          :         :         :         I         :         :         :

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y.
WPCH                                                 ORTHOPEDI

                  MONTH                                 FORECAST
---------------------------------------------------------------------------
                   41     -     -     -     -     -     1041
                   42     -     -     -     -     -     1049
                   43     -     -     -     -     -     1056
                   44     -     -     -     -     -     1064
                   45     -     -     -     -     -     1071
                   46     -     -     -     -     -     1079
                   47     -     -     -     -     -     1087
                   48     -     -     -     -     -     1094
---------------------------------------------------------------------------
  BASED ON  40  PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82
```

TABLE 7

FORECAST PEDIATRICS UNIT

MODEL	PARAMETER	MEAN ABS PCT ERROR
1 . LINEAR REGRESSION	INTERCEPT= 274 SLOPE= 0.54	19.0%
2 . SIMPLE MOVING AVERAGE	N= 5	16.9%
3 . DOUBLE MOVING AVERAGE	N= 5	18.9%
4 . SIMPLE EXPONENTIAL SMOOTHING	ALPHA=0.30	16.1%
5 . DOUBLE EXPONENTIAL SMOOTHING	ALPHA=0.30	17.7%
6 . ADDITIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	15.7%
7 . MULTIPLICATIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	15.9%

(STATISTICS BASED ON FIRST 36 MONTHS) ENTER SELECTION #? 6.
SELECT YOUR CONSTANTS (ENTER 0 FOR DEFAULT VALUES: .2,.1,.05)
ALPHA = ? 0.2
BETA = ? 0.1
GAMMA = ? 0.05

A D D I T I V E   S E A S O N A L   S M O O T H I N G

MONTH	ACTUAL	FORECAST	ERROR
37	282	276	6
38	232	298	-66
39	221	269	-48
40	333	298	35

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 38.8   MEAN ABS. PCT. ERROR = 15.7%

WANT THE MOVING RANGE TEST? Y.

```
  -103.5   -69.0   -34.5      0     34.5    69.0   103.5
  (LCL)---------------------------------------------------(UCL)

MONTH   :        :       :        I       :       :       :
 37                                *
        :        :       :        I       :       :       :
 38              *
        :        :       :        I       :       :       :
 39                  *
        :        :       :        I       :       :       :
 40                                       *
        :        :       :        I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y

WPCH MONTH						PEDIATRIC FORECAST
41	-	-	-	-	-	289
42	-	-	-	-	-	271
43	-	-	-	-	-	283
44	-	-	-	-	-	269
45	-	-	-	-	-	319
46	-	-	-	-	-	289
47	-	-	-	-	-	272
48	-	-	-	-	-	284

BASED ON 40 PREVIOUS MONTHS : 10/31/82 THROUGH 01/31/62

TABLE 8

FORECAST OBSTETRICS UNIT

```
   MODEL                                           PARAMETER     MEAN ABS
                                                                 PCT ERROR
---------------------------------------------------------------------------
1 . LINEAR REGRESSION                            INTERCEPT= 312     8.2%
                                                   SLOPE= 4.10
2 . SIMPLE MOVING AVERAGE                             N=  5         7.7%
3 . DOUBLE MOVING AVERAGE                             N=  5        17.8%
4 . SIMPLE EXPONENTIAL SMOOTHING                  ALPHA=0.30        5.0%
5 . DOUBLE EXPONENTIAL SMOOTHING                  ALPHA=0.30       10.8%
6 . ADDITIVE SEASONAL SMOOTHING                    ALPHA=0.20       5.9%
                                           BETA= .1    GAMMA= .05
7 . MULTIPLICATIVE SEASONAL SMOOTHING              ALPHA=0.20       8.4%
                                           BETA= .1    GAMMA= .05


 (STATISTICS BASED ON FIRST  36 MONTHS)   ENTER SELECTION #? 4.
   S I M P L E   E X P O N E N T I A L   S M O O T H I N G
   =========================================================

ENTER THE SMOOTHING CONSTANT 'ALPHA' (0-1)? 0.14
  MONTH            ACTUAL            FORECAST             ERROR
   37               447                434                 13
   38               425                436                -11
   39               427                434                 -7
   40               437                433                  4
 -------------------------------------------------------------------
                      I  S T A T I S T I C S  I
                       .........................
MEAN ABS. DEVIATION =    8.8     MEAN ABS. PCT. ERROR =   2.0%

WANT THE MOVING RANGE TEST? Y.

                         ..................

       -23.4    -15.6     -7.8      0        7.8     15.6     23.4
     (LCL)--------------------------------------------------------(UCL)

MONTH    :        :         :        I        :        :        :
 37                                                  *
         :        :         :        I        :        :        :
 38                   *
         :        :         :        I        :        :        :
 39                         *
         :        :         :        I        :        :        :
 40                                      *
         :        :         :        I        :        :        :

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y.
WPCH                                                OBSTETRIC

                MONTH                                 FORECAST
------------------------------------------------------------------------
                 41     -     -     -     -     -     434
                 42     -     -     -     -     -     434
                 43     -     -     -     -     -     434
                 44     -     -     -     -     -     434
                 45     -     -     -     -     -     434
                 46     -     -     -     -     -     434
                 47     -     -     -     -     -     434
                 48     -     -     -     -     -     434
------------------------------------------------------------------------
  BASED ON  40  PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82
```

TABLE 9

FORECAST P.C.V. UNIT

MODEL	PARAMETER	MEAN ABS PCT ERROR
1 . LINEAR REGRESSION	INTERCEPT= 310 SLOPE= 5.61	12.1%
2 . SIMPLE MOVING AVERAGE	N= 5	4.6%
3 . DOUBLE MOVING AVERAGE	N= 5	4.7%
4 . SIMPLE EXPONENTIAL SMOOTHING	ALPHA=0.30	4.6%
5 . DOUBLE EXPONENTIAL SMOOTHING	ALPHA=0.30	5.6%
6 . ADDITIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	7.6%
7 . MULTIPLICATIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	10.0%

(STATISTICS BASED ON FIRST 35 MONTHS) ENTER SELECTION #? 2.

S I M P L E   M O V I N G   A V E R A G E

MONTH	ACTUAL	FORECAST	ERROR
36	430	461	-31
37	469	458	11
38	471	458	13
39	489	459	30

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 21.3   MEAN ABS. PCT. ERROR = 4.6%

WANT THE MOVING RANGE TEST? Y

```
      -56.7   -37.8   -18.9     0     18.9    37.8    56.7
      (LCL)---------------------------------------------------(UCL)

MONTH   :       :       :       I       :       :       :
 36               *
        :       :       :       I       :       :       :
 37                                 *
        :       :       :       I       :       :       :
 38                                  *
        :       :       :       I       :       :       :
 39                                           *
        :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y.

WPCH PCV

MONTH						FORECAST
40	-	-	-	-	-	468
41	-	-	-	-	-	468
42	-	-	-	-	-	468
43	-	-	-	-	-	468
44	-	-	-	-	-	468
45	-	-	-	-	-	468
46	-	-	-	-	-	468
47	-	-	-	-	-	468

BASED ON 39 PREVIOUS MONTHS : 10/31/82 THROUGH 01/31/82

TABLE 10

FORECAST I.C.U. UNIT

MODEL	PARAMETER	MEAN ABS PCT ERROR
1 . LINEAR REGRESSION	INTERCEPT= 221 SLOPE= 1.73	7.9%
2 . SIMPLE MOVING AVERAGE	N= 5	6.4%
3 . DOUBLE MOVING AVERAGE	N= 5	14.3%
4 . SIMPLE EXPONENTIAL SMOOTHING	ALPHA=0.30	4.4%
5 . DOUBLE EXPONENTIAL SMOOTHING	ALPHA=0.30	9.1%
6 . ADDITIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	4.1%
7 . MULTIPLICATIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	5.6%

(STATISTICS BASED ON FIRST 36 MONTHS) ENTER SELECTION #? 6
SELECT YOUR CONSTANTS (ENTER 0 FOR DEFAULT VALUES: .2,.1,.05)
ALPHA = ? 0.2
BETA = ? 0.1
GAMMA = ? 0.05.

A D D I T I V E   S E A S O N A L   S M O O T H I N G

MONTH	ACTUAL	FORECAST	ERROR
37	252	280	-28
38	293	294	-1
39	271	271	0
40	265	278	-13

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 10.5   MEAN ABS. PCT. ERROR = 4.1%

WANT THE MOVING RANGE TEST? Y.

```
     -28.0   -18.7    -9.3      0      9.3    18.7    28.0
     (LCL)-----------------------------------------------------(UCL)

MONTH   :       :       :       I       :       :       :
 37     *
        :       :       :       I       :       :       :
 38                            *
        :       :       :       I       :       :       :
 39                             *
        :       :       :       I       :       :       :
 40                 *
        :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y.

WPCH ICU

MONTH	FORECAST
41 - - - - - -	290
42 - - - - - -	280
43 - - - - - -	303
44 - - - - - -	281
45 - - - - - -	287
46 - - - - - -	297
47 - - - - - -	287
48 - - - - - -	310

BASED ON 40 PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82

TABLE 11

FORECAST C.C.U. UNIT

```
##      MODEL                                          PARAMETER     MEAN ABS
                                                                     PCT ERROR
------------------------------------------------------------------------------
 1 . LINEAR REGRESSION                           INTERCEPT= 143       2.9%
                                                    SLOPE= 1.26
 2 . SIMPLE MOVING AVERAGE                             N=  6          8.3%
 3 . DOUBLE MOVING AVERAGE                             N=  6         13.9%
 4 . SIMPLE EXPONENTIAL SMOOTHING                  ALPHA=0.15         6.5%
 5 . DOUBLE EXPONENTIAL SMOOTHING                  ALPHA=0.15         4.8%
 6 . ADDITIVE SEASONAL SMOOTHING                   ALPHA=0.20         4.0%
                                          BETA= .1    GAMMA= .05
 7 . MULTIPLICATIVE SEASONAL SMOOTHING             ALPHA=0.20         6.9%
                                          BETA= .1    GAMMA= .05

  (STATISTICS BASED ON FIRST  35 MONTHS)   ENTER SELECTION #? 1.
*****************************************************************
*                      P A R A M E T E R S                      *
*                      ...................                      *
*         INTERCEPT= 142.7         SLOPE=    1.3                *
*****************************************************************
   MONTH           ACTUAL            FORECAST              ERROR
     36             185                188                   -3
     37             187                189                   -2
     38             185                191                   -6
     39             203                192                   11
-----------------------------------------------------------------
                     I  S T A T I S T I C S  I
                     .........................
MEAN ABS. DEVIATION =     5.6     MEAN ABS. PCT. ERROR =    2.9%

WANT THE MOVING RANGE TEST? Y
                                 .................

      -15.0    -10.0     -5.0       0      5.0      10.0     15.0
    (LCL)---------------------------------------------------------(UCL)

MONTH    :        :        :        I        :        :        :
 36                          *
         :        :        :        I        :        :        :
 37                            *
         :        :        :        I        :        :        :
 38                      *
         :        :        :        I        :        :        :
 39                                                    *
         :        :        :        I        :        :        :

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y.
WPCH                                               CCU

                 MONTH                               FORECAST
---------------------------------------------------------------------
                  40     -     -     -     -     -     193
                  41     -     -     -     -     -     195
                  42     -     -     -     -     -     196
                  43     -     -     -     -     -     197
                  44     -     -     -     -     -     198
                  45     -     -     -     -     -     200
                  46     -     -     -     -     -     201
                  47     -     -     -     -     -     202
---------------------------------------------------------------------
  BASED ON   39   PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82
```

TABLE 12

FORECAST NURSERY UNIT

	MODEL	PARAMETER	MEAN ABS PCT ERROR
1 .	LINEAR REGRESSION	INTERCEPT= 297 SLOPE= 3.44	5.6%
2 .	SIMPLE MOVING AVERAGE	N= 6	6.7%
3 .	DOUBLE MOVING AVERAGE	N= 6	17.1%
4 .	SIMPLE EXPONENTIAL SMOOTHING	ALPHA=0.15	3.1%
5 .	DOUBLE EXPONENTIAL SMOOTHING	ALPHA=0.15	6.2%
6 .	ADDITIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	5.3%
7 .	MULTIPLICATIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	7.4%

(STATISTICS BASED ON FIRST 36 MONTHS) ENTER SELECTION #? 6

SELECT YOUR CONSTANTS (ENTER 0 FOR DEFAULT VALUES: .2,.1,.05)

ALPHA = ? 0.05
BETA = ? 0.1
GAMMA = ? 0.05

A D D I T I V E   S E A S O N A L   S M O O T H I N G

MONTH	ACTUAL	FORECAST	ERROR
37	447	473	-26
38	409	419	-10
39	411	452	-41
40	404	395	9

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 21.5   MEAN ABS. PCT. ERROR = 5.1%

WANT THE MOVING RANGE TEST? Y

```
     -57.4   -38.3   -19.1     0     19.1    38.3    57.4
    (LCL)---------------------------------------------------(UCL)

MONTH  :       :       :       I       :       :       :
  37               *
       :       :       :       I       :       :       :
  38                        *
       :       :       :       I       :       :       :
  39         *
       :       :       :       I       :       :       :
  40                              *
       :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y.

WPCH NURSERY

MONTH						FORECAST
41	-	-	-	-	-	391
42	-	-	-	-	-	428
43	-	-	-	-	-	409
44	-	-	-	-	-	412
45	-	-	-	-	-	434
46	-	-	-	-	-	458
47	-	-	-	-	-	515
48	-	-	-	-	-	473

BASED ON 40 PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82

TABLE 13

FORECAST TOTAL UNITS

MODEL	PARAMETER	MEAN ABS PCT ERROR
1 . LINEAR REGRESSION	INTERCEPT=5989 SLOPE=27.70	5.8%
2 . SIMPLE MOVING AVERAGE	N= 5	3.9%
3 . DOUBLE MOVING AVERAGE	N= 5	5.3%
4 . SIMPLE EXPONENTIAL SMOOTHING	ALPHA=0.30	4.3%
5 . DOUBLE EXPONENTIAL SMOOTHING	ALPHA=0.30	4.8%
6 . ADDITIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	4.9%
7 . MULTIPLICATIVE SEASONAL SMOOTHING	ALPHA=0.20 BETA= .1 GAMMA= .05	3.7%

(STATISTICS BASED ON FIRST 36 MONTHS) ENTER SELECTION #? 7.
SELECT YOUR CONSTANTS (ENTER 0 FOR DEFAULT VALUES: .2,.1,.05)
ALPHA = ? 0.2
BETA = ? 0.1
GAMMA = ? 0.05

M U L T I P L I C A T I V E S E A S O N A L
S M O O T H I N G (W I N T E R S')

MONTH	ACTUAL	FORECAST	ERROR
37	6762	6693	69
38	6694	6624	70
39	6229	6672	-443
40	7146	6731	415

I S T A T I S T I C S I

MEAN ABS. DEVIATION = 249.3 MEAN ABS. PCT. ERROR = 3.7%

WANT THE MOVING RANGE TEST? Y

```
      -665.5  -443.7  -221.8      0     221.8   443.7   665.5
      (LCL)-------------------------------------------------(UCL)

MONTH    :       :       :       I       :       :       :
 37                                *
         :       :       :       I       :       :       :
 38                                *
         :       :       :       I       :       :       :
 39              *
         :       :       :       I       :       :       :
 40                                              *
         :       :       :       I       :       :       :
```

WANT TO FORECAST WITH THIS MODEL (Y/N)? Y
WPCH

MONTH						TOTAL FORECAST
41	-	-	-	-	-	7360
42	-	-	-	-	-	6739
43	-	-	-	-	-	6656
44	-	-	-	-	-	6669
45	-	-	-	-	-	6862
46	-	-	-	-	-	7387
47	-	-	-	-	-	6763
48	-	-	-	-	-	6680

BASED ON 40 PREVIOUS MONTHS : 10/31/79 THROUGH 01/31/82

Moving Average or Multiplicative Seasonal Smoothing Models (with smaller MAPE) is that the Double Moving Average Model is superior in the Moving Range Test than the other two models (i.e., both of the other two models failed in the Moving Range Test. See Tables 2 and 3). The reason why the other two models failed in the Moving Range Test is that the fluctuation shown on the historical record of this unit can't exactly fit the patterns of the other two models. Some particular values, for example data of the 38th month when it was forecasted with Multiplicative Seasonal Smoothing Model and data of the 40th month when it was forecasted with Double Moving Average model, always fell outside the control limit in the Moving Range Control Chart. After selecting the appropriate model finding the best fitting corresponding parameter(s), α = 0.18, by trial and error, the computer prints out the forecasted value and error for the remaining four periods. After getting a MAPE of 3.4% associated with this Double Exponential Smoothing model, the Moving Range Test was done for the remaining periods' data. Because there is no out-of-control condition in the Moving Range Test Chart, it was decided to forecast with this Double Exponential Smoothing model.

The forecasting result of each unit in the hospital is summarized in Table 14. Each forecasted value is derived from the appropriate mathematical formula corresponding to the selected model and assigned parameter(s). For example, when the linear regression model was selected to forecast the patient census of C.C.U. unit

TABLE 14

SUMMARY OF FORECASTING PATIENT CENSUS

UNIT	SELECTED MODEL	MATHEMATICAL FORMULA	MAPE
MEDICAL	DOUBLE EXPONENTIAL SMOOTHING, α=0.18	$X_{40+t}=[2+0.22t]S_{40}-(1+0.22t)S_{40}^{[2]}$	3.4%
SURGICAL	ADDITIVE SEASONAL SMOOTHING α=0.03, B=0.1, r=0.05	$X_{40+t}(40)=b_1(40)+b_2(40)\ .\ t+C_{40+t}(28-t)$ $t=1,2,---8$	8.8%
MEDICAL SURGICAL	DOUBLE MOVING AVERAGE SMOOTHING N=8	$X_{40+t}(40)=2M_{40}-M_{40}^{[2]}+0.29t[M_{40}-M_{40}^{[2]}]$ $t=1,2,---8$	5.6%
ORTHOPEDICS	DOUBLE EXPONENTIAL SMOOTHING, α=0.1	$X_{40+t}(40)=(2+0.11t)S_{40}-(1+0.11t)S_{40}^{[2]},\ t=1,2,---8$	4.3%
PEDIATRICS	ADDITIVE SEASONAL SMOOTHING, α=0.2, B=0.1, Y=0.05	$X_{40+t}(40)=b_1(40)+b_2(40)\ .\ t+C_{40+t}(28+t)$ $t=1,2,---8$	15.7%
OBSTETRICS	SIMPLE EXPONENTIAL SMOOTHING, α=0.14	$X_{40+t}(40)=61+0.86\cdot S_{39}\quad t=1,2,---8$	2.0%

TABLE 14-Continued

UNIT	SELECTED MODEL	MATHEMATICAL FORMULA	MAPE
P.V.C.	SIMPLE MOVING AVERAGE, N=5	$X_{39+t}(39)=M_{39}+9 \quad t=1,2,---8$	4.6%
I.C.U.	ADDITIVE SEASONAL SMOOTHING, $\alpha=0.2$, B=0.1, r=0.5	$X_{40+t}(40)=b_1(40)+b_2(40)\ .\ t + C_{40+t}(28+t)$ $t=1,2,---8$	4.1%
C.C.U.	LINEAR REGRESSION INTERCEPT=142.7, SLOP=1.3	$X_{39+t}(39)=142.7+1.3(38+t)$ $t=1,2,---8$	2.9%
NURSERY	ADDITIVE SEASONAL SMOOTHING, $\alpha=0.05$, B=0.01, Y=0.05	$X_{40+t}(40)=b_1(40)+b_2(40)\ .\ t + C_{40+t}(28+t)$ $t=1,2,---8$	5.1%
TOTAL	MULTIPLICATIVE SEASONAL SMOOTHING $\alpha=0.2$, B=0.1, r=0.05	$X_{40+t}(40)=[b_1(40)+b_2(40)\ .\ t]\ .\ C_{40+t}(28+t)$ $t=1,2,---8$	3.7%

(see Table 11), the corresponding model is X_{39+t}=142.7+1.3 (38+t) where t=1,2,---8. The forecasted value for the 40th month is 193 when t=1 is plugged into this linear regression formula. The mean absolute percentage error for this model was 2.9% when the last four months of data were used as error measurement.

When new data is gathered, the mathematical formula of each model are automatically updated by COFORAN. For example, when the additive seasonal smoothing model was selected to forecast the patient census of the surgical unit (see Table 4) the corresponding formula is $X_{40+t}(40)=b_1(40)+b_2(40).t + C_{40+t}(28+t)$ t=1,2,---8, α=0.03, B=0,1, r=0.05. When a new actual value, for example X_{41}, is given, then $b_1(41)$, $b_2(41)$, $C_1(41)$ will be updated according to the following formula:

$$b_1(41)=0.03[x_{41}-C_{41}(29)]+0.97[b_1(40)+b_2(40)]$$

$$b_2(41)=0.1[b_1(41)-b_1(40)]+0.9\ b_2(40)$$

$$C_{41}(41)=0.05[x_{41}-b_1(41)]+0.95\ C_{41}(29)$$

The detailed examples of how to update each model type when a new value is available, are illustrated in Table 15.

The historical and forecasted data are plotted on the scale paper shown in Graphs 1-11. The solid line indicates the historical record; the dotted line shows the predicted value of the future patient census.

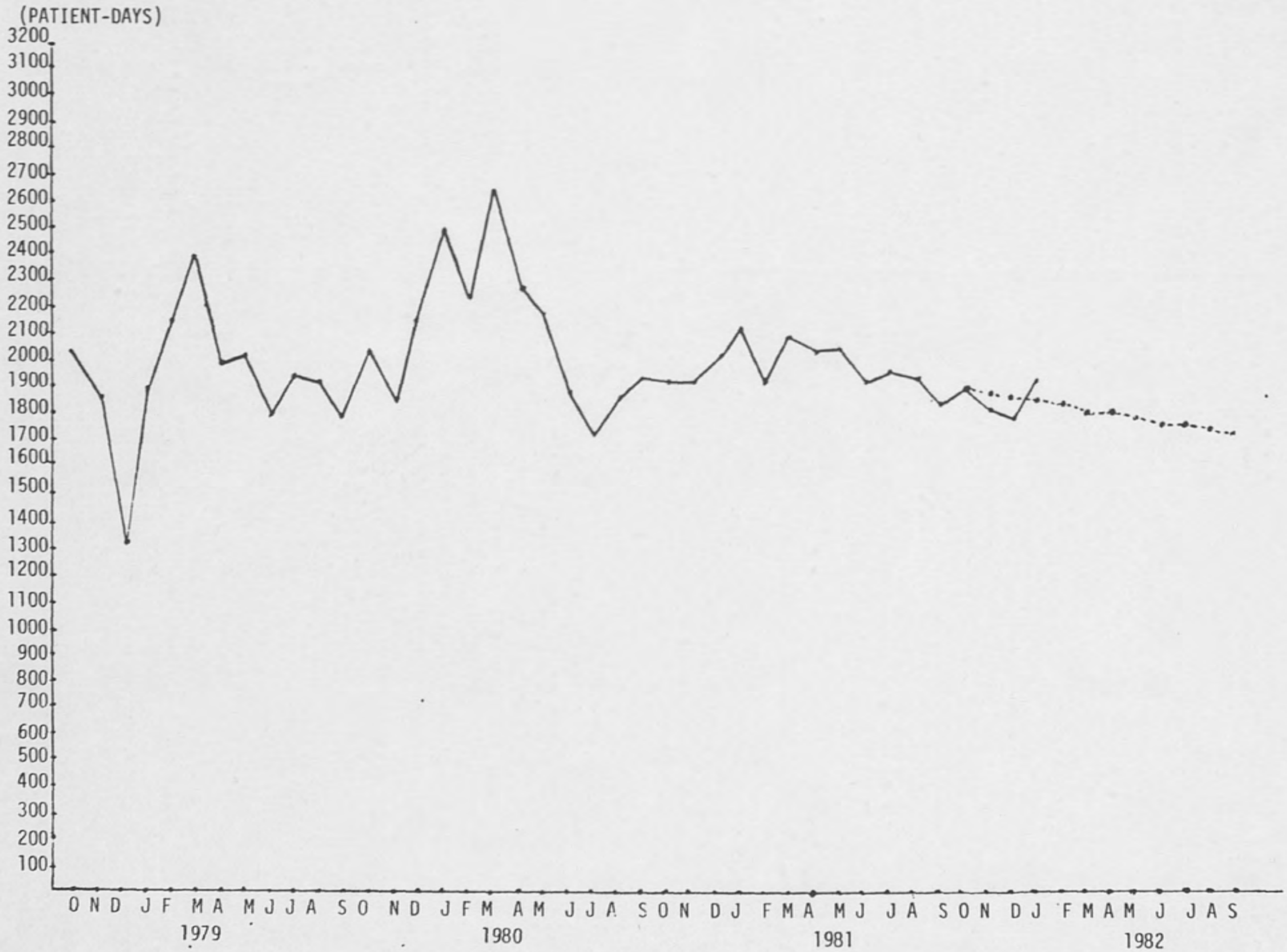
TABLE 15

UPDATED MATHEMATICAL FORMULA FOR A NEW AVAILABLE DATA

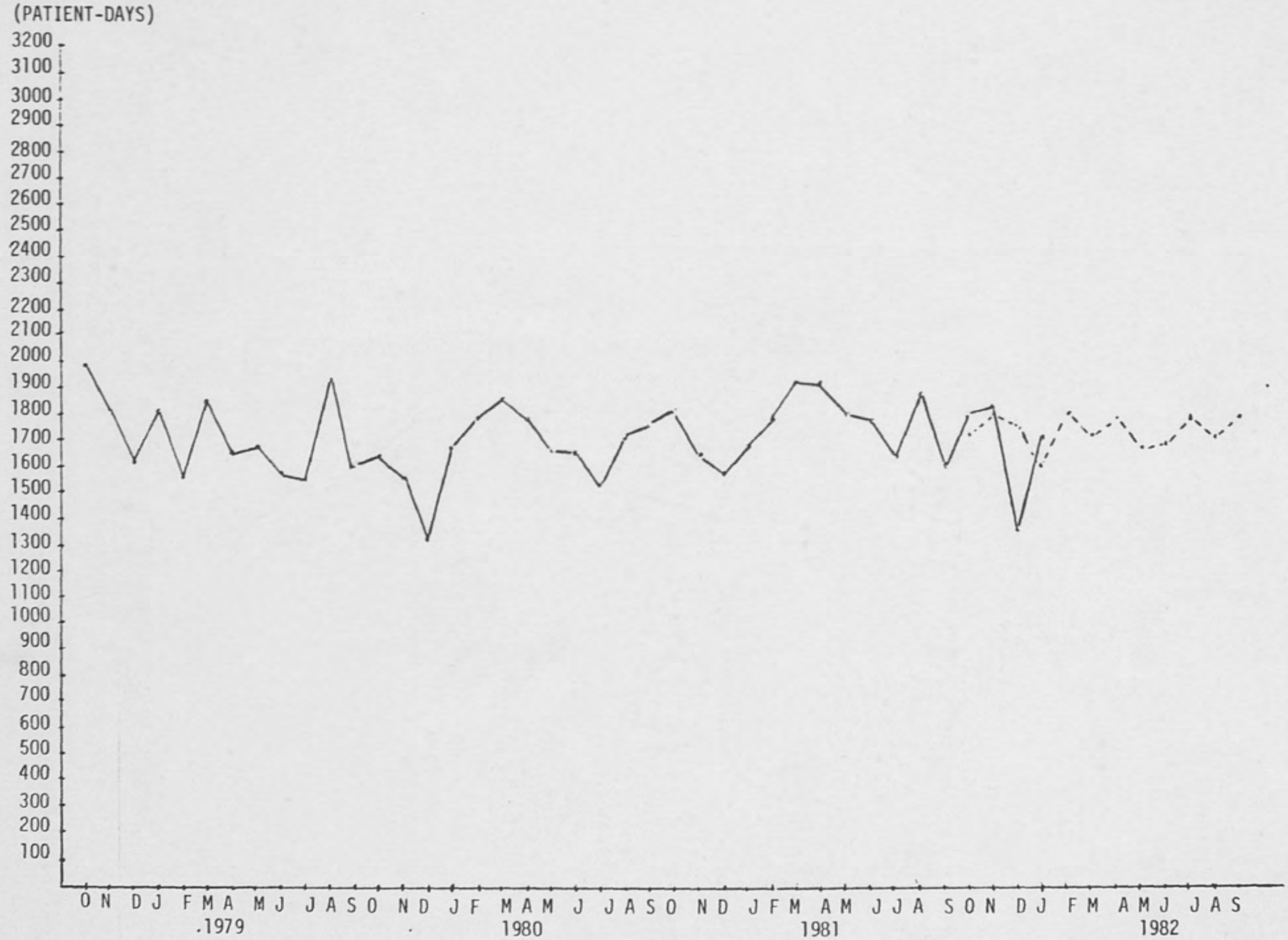
MODEL	NEW INPUT DATA	UPDATED MATHEMATICAL FORMULA
LINEAR REGRESSION	X_{41}	$X_{41+t}(41)=a+b(40+t)$ $a=\frac{2[2(41)+1]}{41(41-1)}\sum_{t=1}^{41} X_t - \frac{6}{41(41-1)}\sum_{t=1}^{41} tX_t$ $b=\frac{12}{41[(41)^2-1]}\sum_{t=1}^{4=1} t\cdot X_t - \frac{6}{41(41-1)}\sum_{t=1}^{41} X_t$
SIMPLE MOVING AVERAGE	X_{41}	$X_{41+t}(41)=M_{41}+(X_{41}-X_{36})/N$
DOUBLE MOVING AVERAGE	X_{41}	$X_{41+t}(41)=2M_{41}-M_{41}^{[2]}+(\frac{2}{N-1})+[M_{41}-M_{41}^{[2]}]$
SIMPLE EXPONENTIAL SMOOTHING	X_{41}	$X_{41+t}(41)=\alpha X_{41}+(1-\alpha)S_{40}$

TABLE 15-Continued

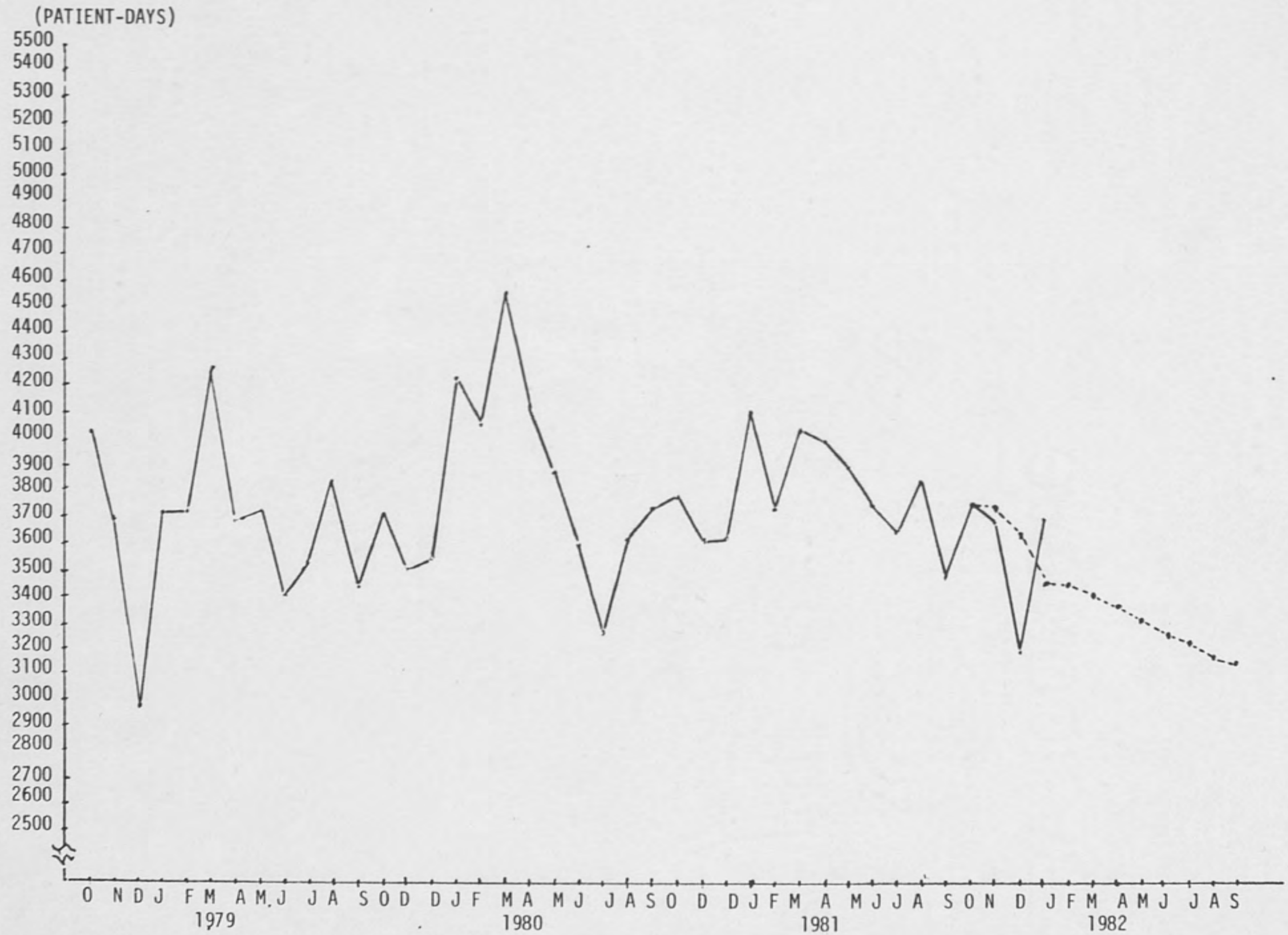
MODEL	NEW INPUT DATE	UPDATED MATHEMATICAL FORMULA
DOUBLE EXPONENTIAL SMOOTHING	X_{41}	$X_{41+t}(41)=(2+\frac{\alpha}{1-\alpha}t)S_{41}-(1+\frac{\alpha}{1-\alpha}t)S_{41}^{[2]}$
MULTIPLICATIVE SEASONAL SMOOTHING	X_{41}	$X_{41+t}(41)=[b_1(41)+b_2(41)\ .\ t]\ .\ C_{41+t}(29+t)$
		$b_1(41)=\alpha[X_{41}/C_{41}(29)]+(1-\alpha)[b_1(40)+b_2(40)]$
		$b_2(41)=\beta[b_1(41)-b_1(40)]+(1-\beta)b_2(40)$
		$C_{41}(41)=\gamma X_{41}/b_1(41)+(1-\gamma)C_{41}(29)$
ADDITIVE SEASONAL SMOOTHING	X_{41}	$X_{41+t}(41)=b_1(41)+b_2(41)\ .\ t+C_{41+t}(29+t)$
		$b_1(41)=\alpha[X_{41}-C_{41}(29)]+(1-\alpha)[b_1(40)+b_2(40)]$
		$b_2(41)=\beta(b_1(41)-b_1-40)]+(1-\beta)b_2(40)$
		$C_{41}(41)=\gamma[X_{41}-b_1(41)]+(1-\gamma)C_{41}(29)$



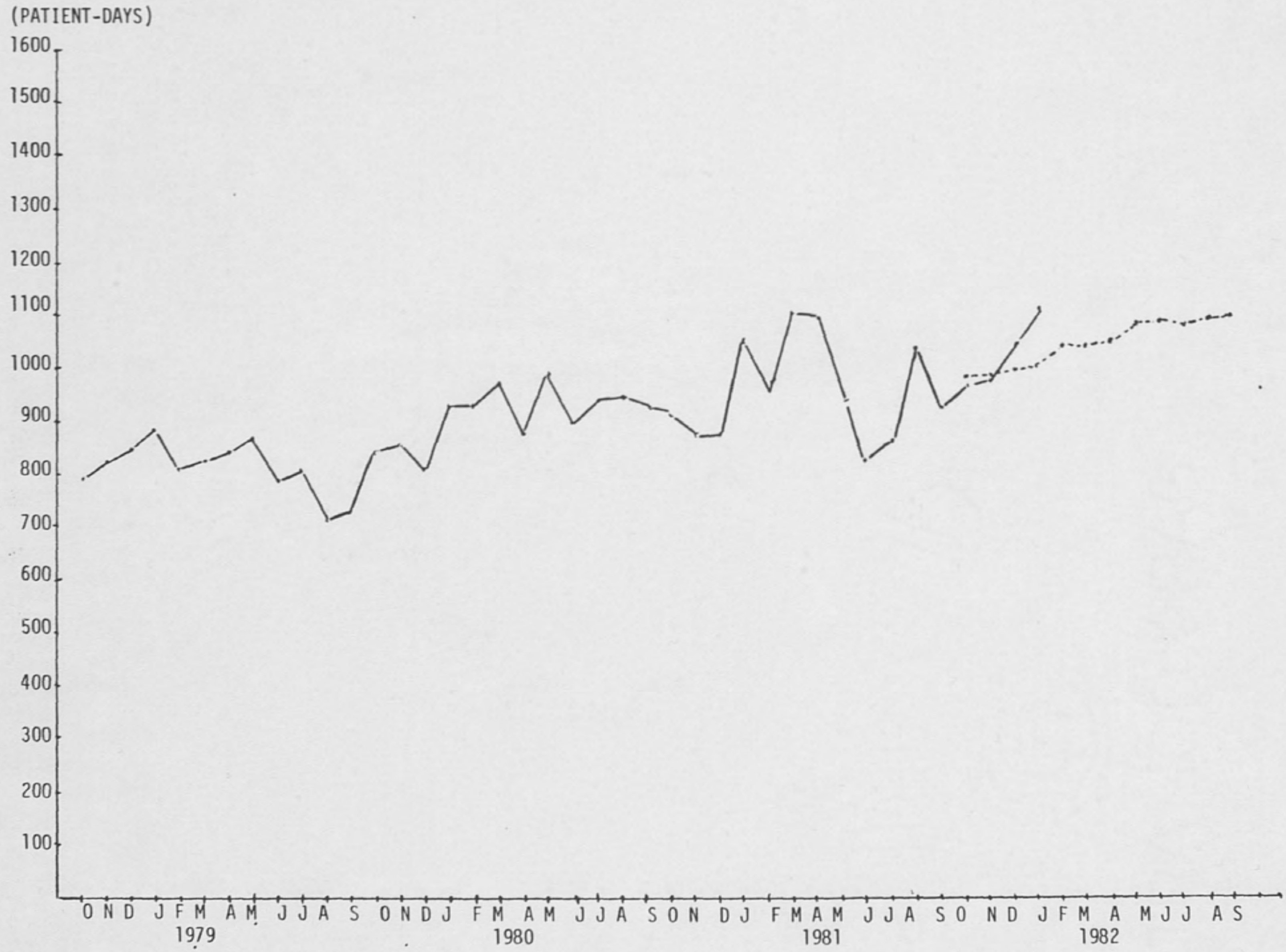
Graph 1. Historical record in medical unit.



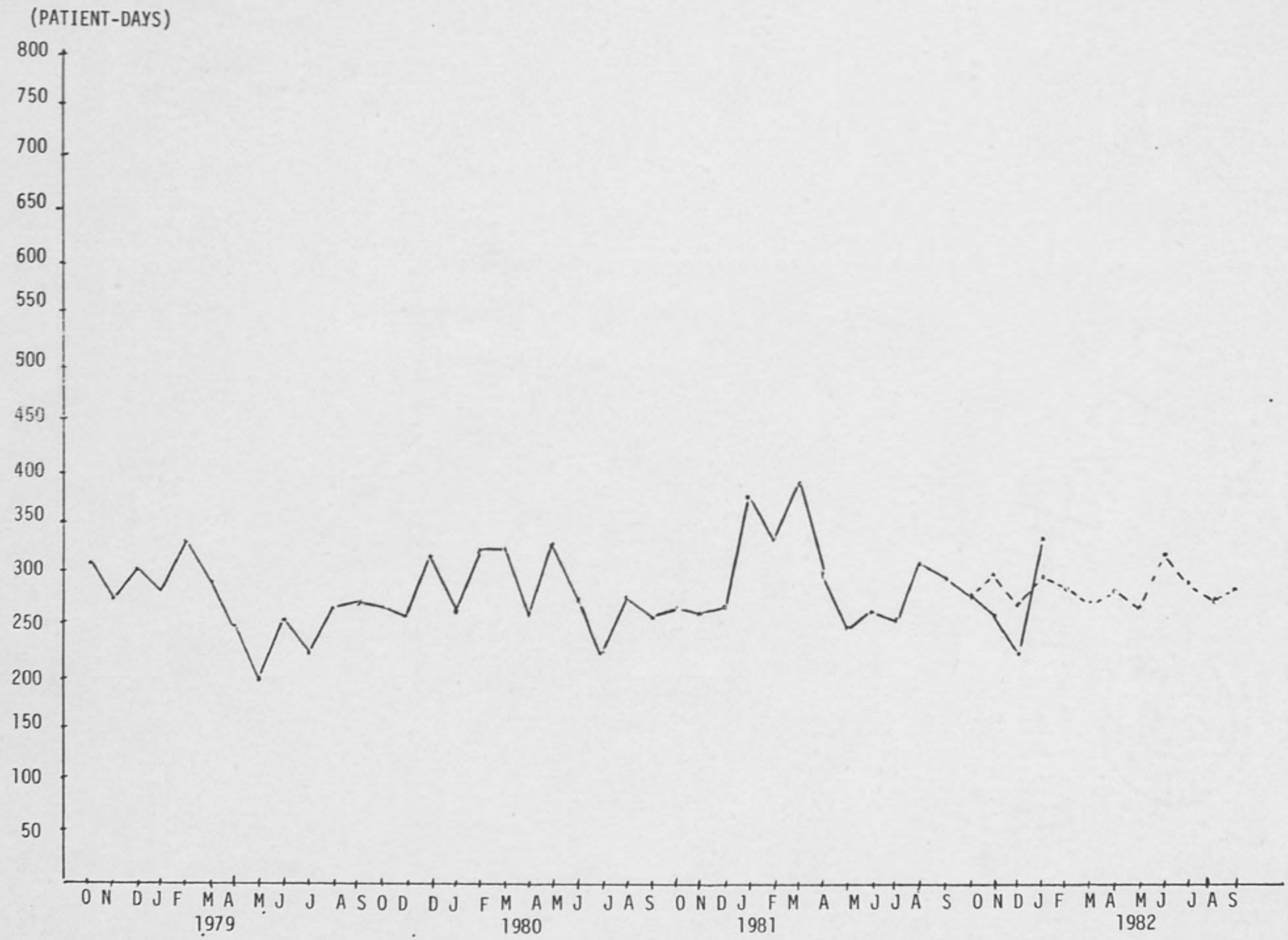
Graph 2. Historical record in surgical unit.



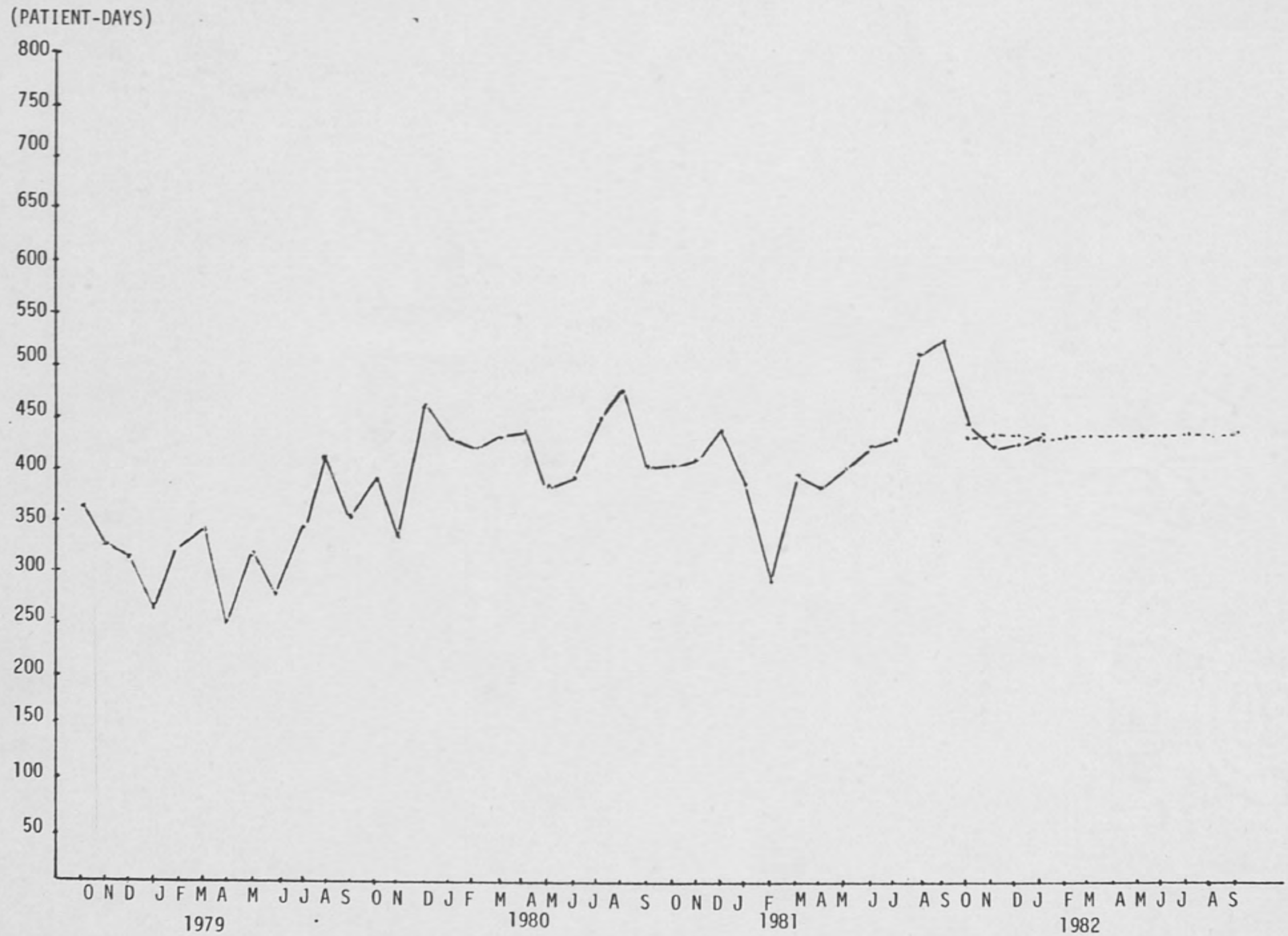
Graph 3. Historical record in medical/surgical unit.



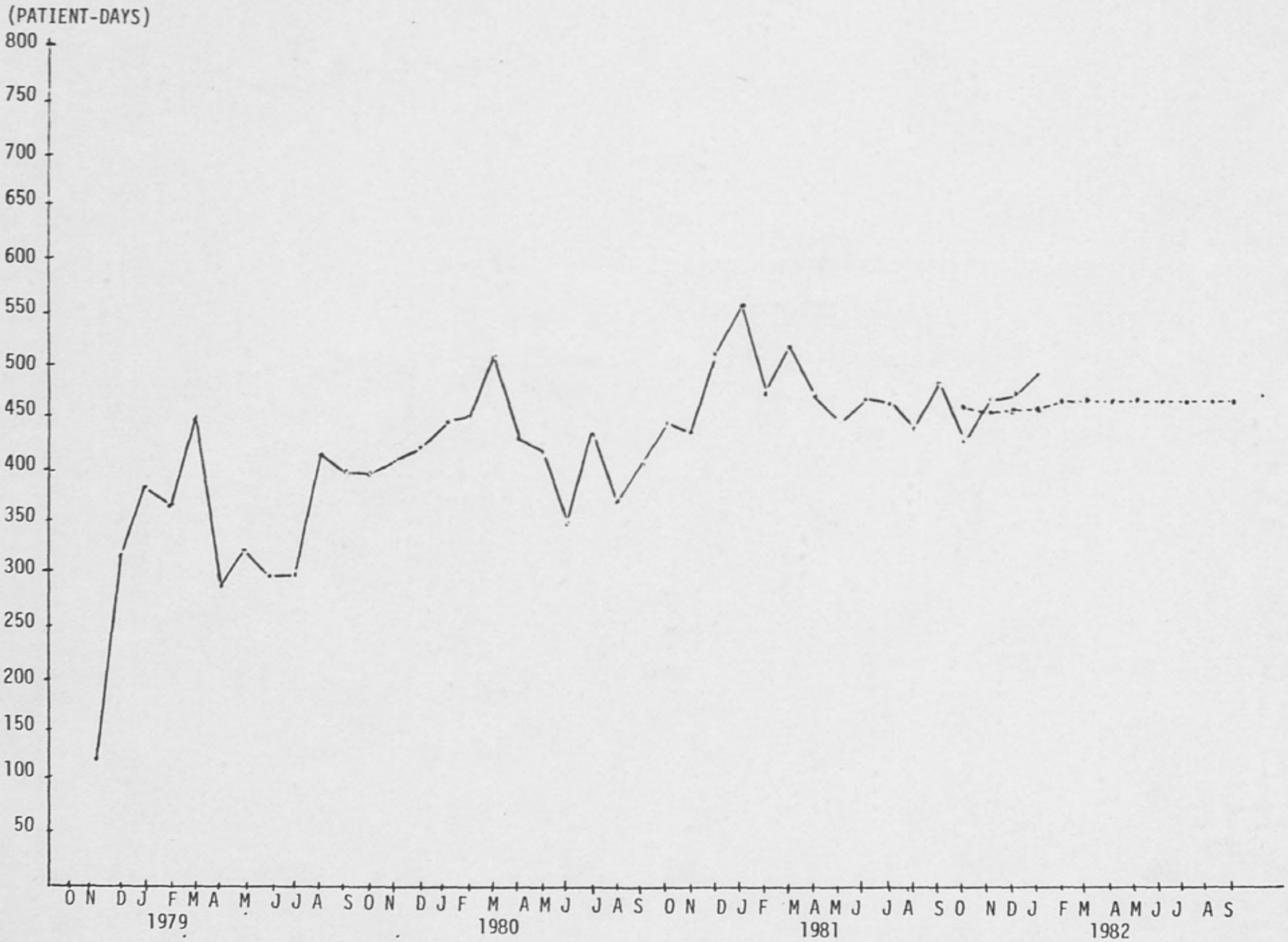
Graph 4. Historical record in orthopedics unit.



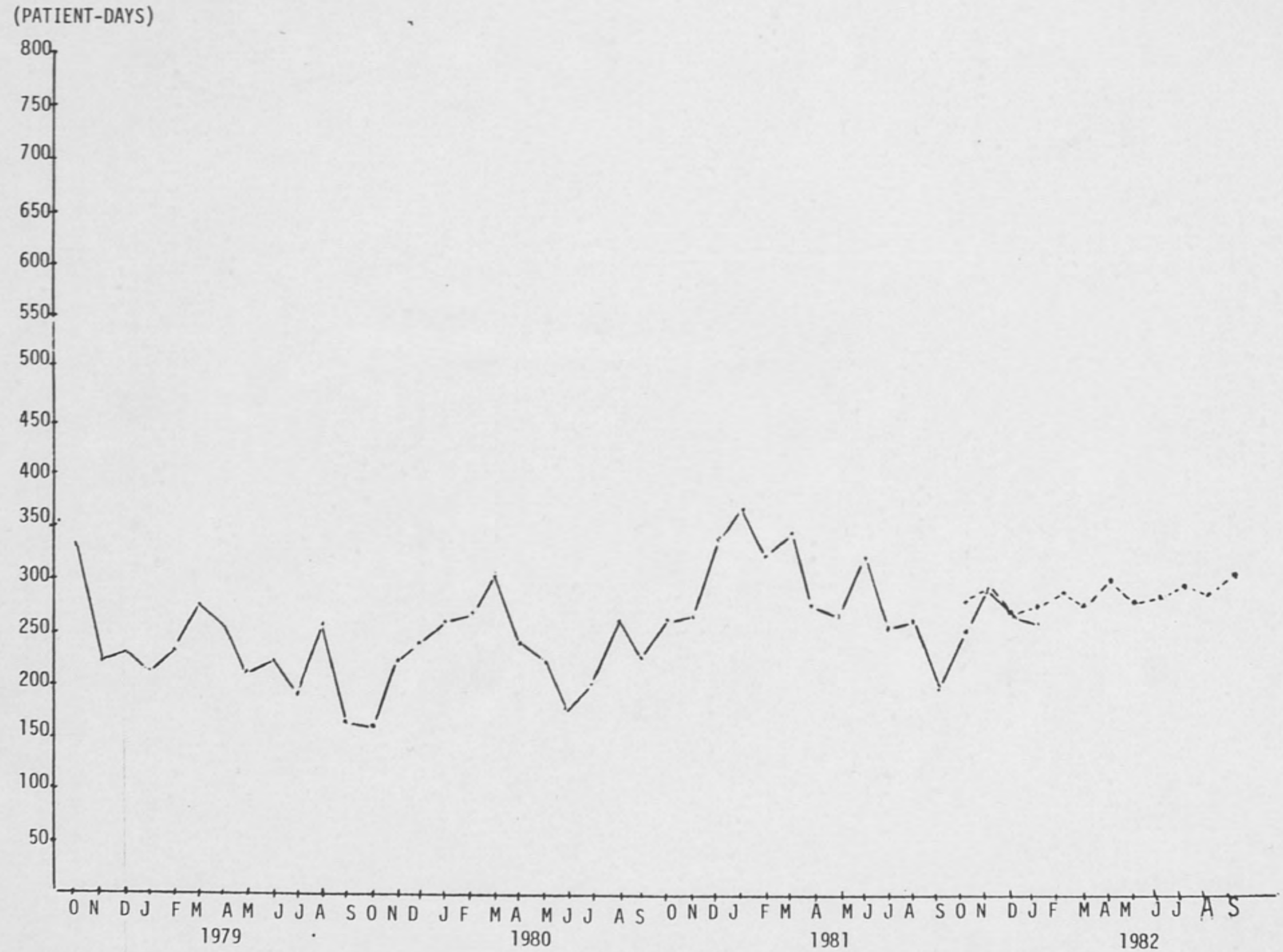
Graph 5. Historical record in pediatrics unit.



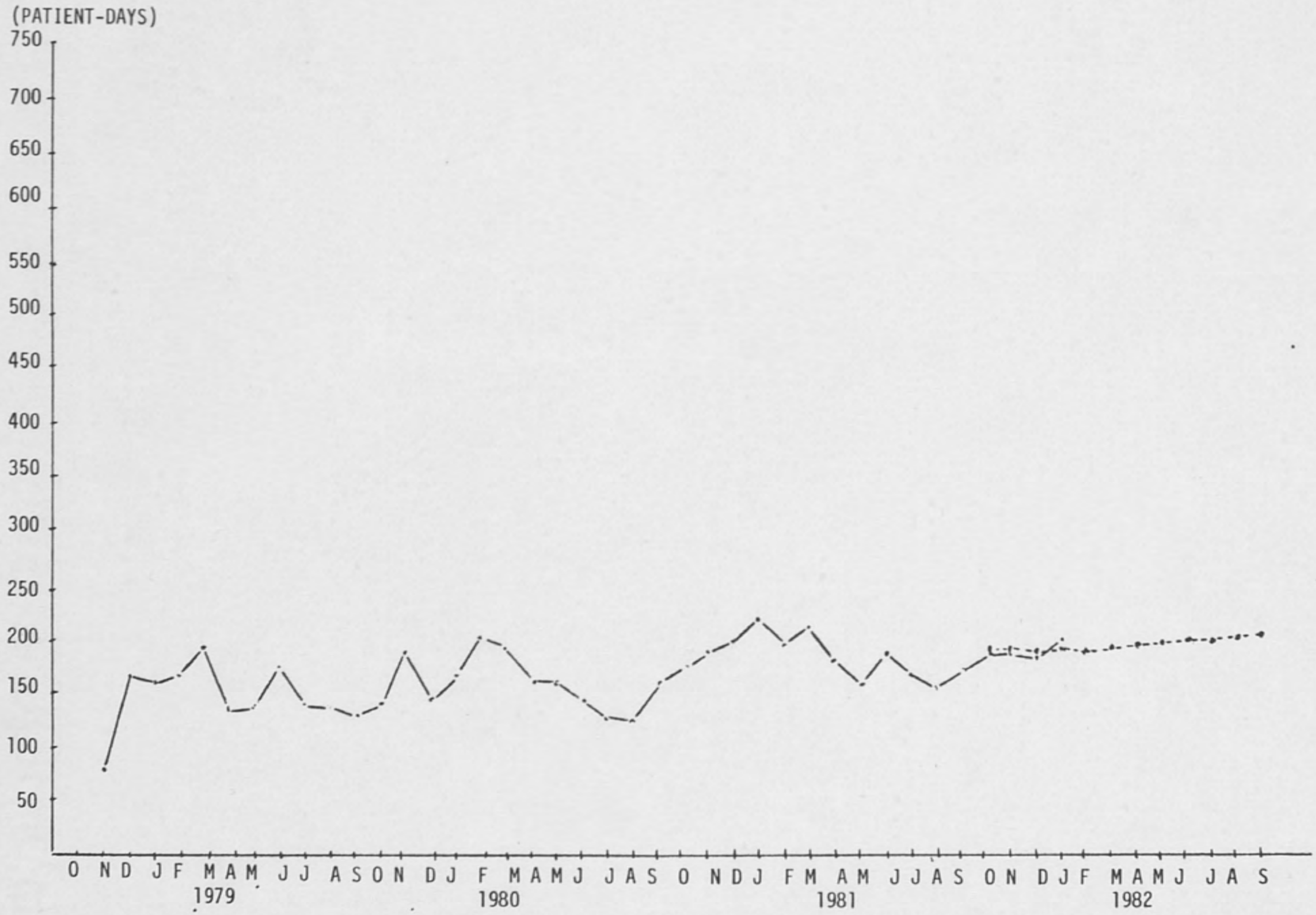
Graph 6. Historical record in obstetrics unit.



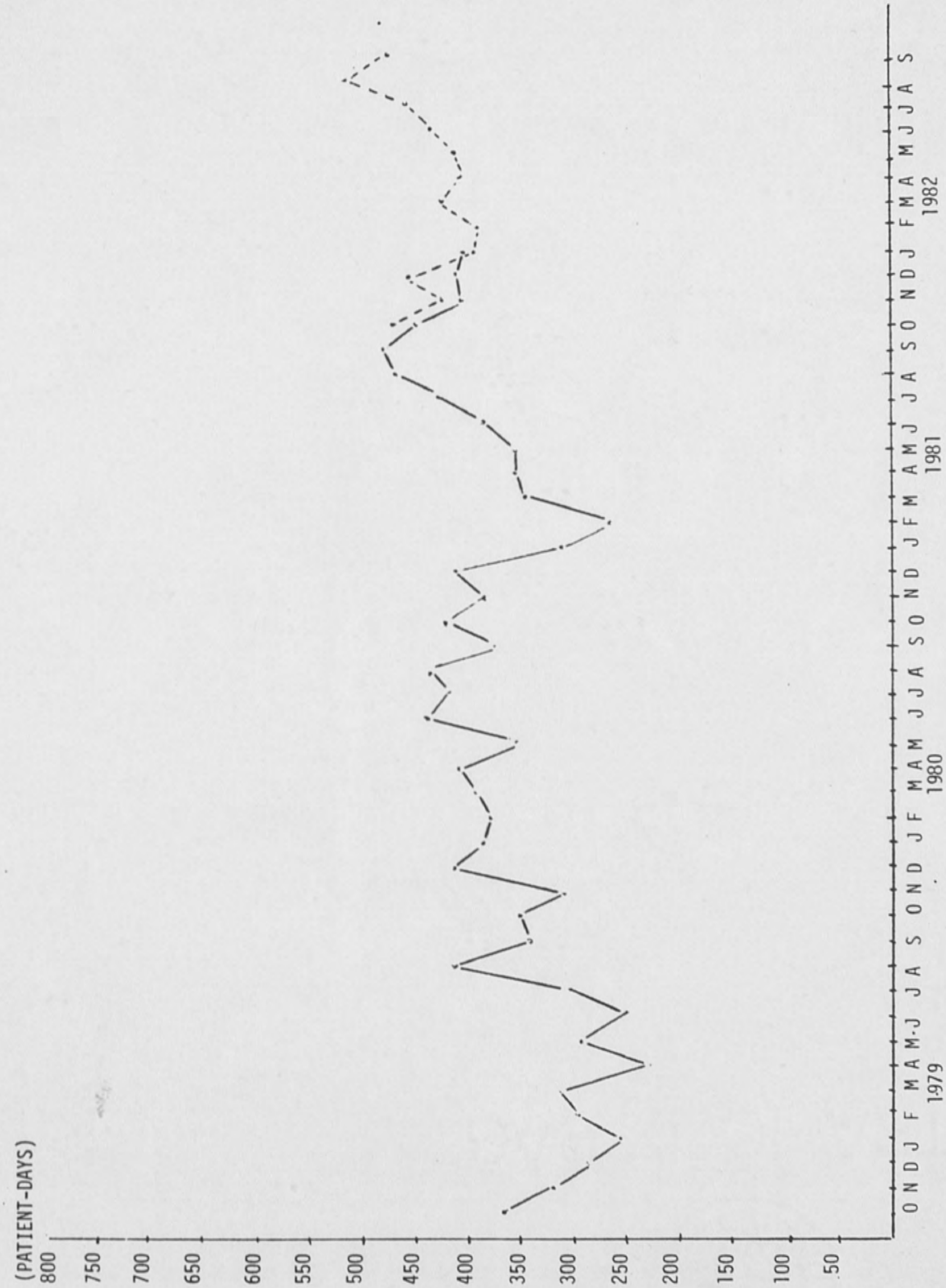
Graph 7. Historical record in P.C.V. unit.



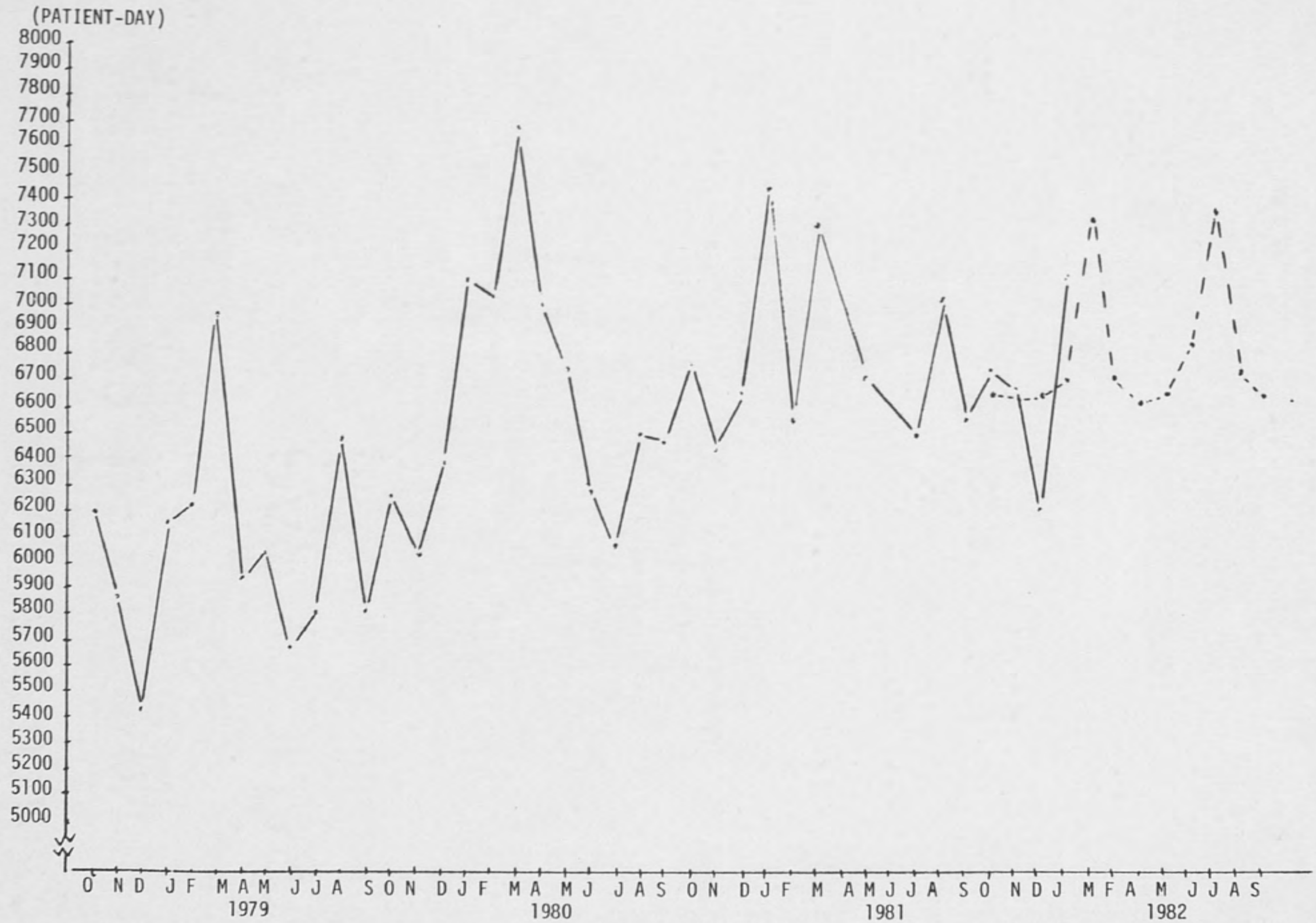
Graph 8. Historical record in I.C.U. unit.



Graph 9. Historical record in C.C.U. unit.



Graph 10. Historical record in nursery unit.



Graph 11. Historical record in total units.

CHAPTER V

ANALYSIS, CONCLUSIONS, AND RECOMMENDATIONS

Since the time series observations are used as the forecasting basis in this research, the historical data should be available to detect obvious or likely mistakes which might affect the forecasting method. For example, in predicting surgical unit patient census, the data of the 39th month always falls outside the control limit (-3 $\overline{MR}$) in the moving range test no matter which forecasting method was chosen. The reason for this might be that the 39th month is December. It is hypothesized that most scheduled surgery patients prefer to stay at home until January, when the holiday season is over. Such data may be untypical and could be excluded from the analysis. But it is not always possible to eliminate all of the unusual data, because that might produce the result of a parameter change in process characteristics. It is better to present those extraordinary or unusual observations to the informed person and let that person make the decision whether to omit the data or not, or to revise the forecast (in this case, December's) accordingly.

Most of the forecasted values in this research appeared very sensible when they were compared with the historical trend or seasonality except these in the Medical, Medical/Surgical, Obstetrics, and P.C.V. units. The reason for these exceptions could be explained as follows: the fluctuations shown on these graphs (see graph 1 for medical unit, graph 3 for medical/surgical unit, graph 6 for obstetrics unit, and graph 7 for P.C.V. unit) do not indicate the exact historical patterns over the entire period to follow. For example, in the medical unit (graph 1), the fluctuation of the record in the year of 1979 and 1980 seems to have the characteristics of seasonality. However, the pattern shown in the year of 1981 indicates a downward trend instead of the seasonal trend. Because these conflicting patterns appeared on the historical record, it is very hard to find a sensible model for these units. The user may eliminate the out-of-date record (for example, record of 1979 and 1980 in the medical unit) and only keep track of the recent up-to-date record.

Except these units, the forecasted results of the remaining units were reasonable to follow when they were compared with the historical patterns of each unit. The pattern shown on the graph of each unit should reflect the particular characteristics of each unit. For example, observing the patient census of the pediatrics unit, it could be found that the patient census was stationary with a seasonal fluctuation. This phenomenon indicated that the patient load of this unit only will be high in winter, and will be low in summer without an obvious increasing trend. On the other hand, the patient census of the nursery unit not only fluctuated with seasonality but also had a increasing trend. These characteristics of historical data's behavior in each unit could bring the management some guidance to allocate the limited health care resource to the different demand of each unit.

Consider the forecasting accuracy of different units' patient census summarized in Table 14. The value of the Mean Absolute Percentage Errors ranges from 2.0% to 15.7% with the mean value of 5,5% ($\overline{\text{M}}$APE=5.5%) and standard deviation of 3.6%. It is a small forecasting error when we convert the Mean Absolute Persentage Error to the actual patient census. For example, consider the Surgical Unit (see graph 2), the forecasted values fluctuate around 1700 patient days per month. Because the Mean Absolute Percentage Error of Surgical Unit is 8.8%, the expected forecasting error is 150 patient days per month. It is a small forecasting deviation to the actual patient census when we think it only 5 patient days' deviation per day to the actual patient census.

For a more advance practical forecasting of the patient census, forecasting system may use a combination of quantitative and qualitative methods. The historical methods used in this research routinely analyze historical data and prepare forecast. The statistical forecast then becomes an input to a subjective evaluation by an informal manager who may modify the forecast in view of other relevant information such as demographic characteristics.

APPENDIX A

CHARACTERISTIC PATTERNS OF THE SERIES

a. Horizontal Pattern

The mathematical formula could be expressed as $d_t=b+e_t$, where d_t is the actual sales over any period t (a random variable), b is the average sale over any period t (a constant), and e_t is a random variable with a mean of zero and constant variance δ_e^2 over time.

b. Trend Pattern

The mathematical formula is $d_t=a+b_t+e_t$ for the linear trend, and $d_t=a+b_t+c_t^2+e_t$ for the quadratic trend.

c. Seasonal Cycle (Multiplicative Model)

The mathematical formula is $d_t=\bar{d}\cdot c_t+e_t$, where $c_t(c_t\geq 0)$ is the seasonal ratio at time t.

d. Trend Seasonal Pattern

Both the trend and seasonal pattern are combined with each other in the historical data. There are two ways to express the combination of these two patterns. The first expression is multiplicative seasonal smoothing which can be formulated as $d_t=(a+b_t)\cdot c_t+e_t$. The other model is additive seasonal smoothing whose mathematical formula is $d_t=(a+b_t)+f_t+e_t$, where f_t is the seasonal increment and $\bar{f}_t$ should be equal to 0 over a seasonal length.

APPENDIX B

FORECASTING MODELS USED IN THIS RESEARCH

a. Linear Regression

Many time series can be adequately described by a simple linear function of time. This function can be written as

$$x_t=b_1+b_2t+e_t$$

where b_1 and b_2 are intercept and slope respectively, and e_t is the random deviation from the mean in time period t with $E(e_t)=0$, Var $(e_t)=\sigma_e^2$. Assume that there are T periods of data available, say x_1, x_2 ---, x_t. By the method of least square, the estimator of b_1 and b_2 are (2).

$$b_1(T) = \frac{2(2T+1)}{T(T-1)} \sum_{t=1}^{T} x_t - \frac{6}{T(T-1)} \sum_{t=1}^{T} tx_t$$

$$b_2(T) = \frac{12}{T(T^2-1)} \sum_{t=1}^{T} tx_t - \frac{6}{T(T-1)} \sum_{t=1}^{T} x_t$$

The forecast, made at the end of period T of an observation in some future time period, say T = t, would be denoted by $X_{T+t}(T)$, and is computed from $X_{T+t}(T)=b_1(T)+b_2(T)\cdot(T+t)$.

As a new observation becomes available, a new updated estimate of b_1 and b_2 will be computed.

b. Simple Moving Average

Suppose that a time series is generated by a constant parameters plus random error such as

$$X_t = b + e_t$$

where $e_t \sim N(0, \sigma^2)$; b is an unknown constant. By using least square technique, the best estimator of b is

$$b = \left(\sum_{t=1}^{T} X_t\right)/T$$

If we want to include only the most recent N observations, the estimator of b becames (13)

$$b = \left(\sum_{t=T-N+1}^{T} X_t\right) / N = M_T$$

where $M_T = (X_T + X_{T-1} \text{----} + X_{T-N+1})/N$

or $M_T = M_{T-1} + (X_T - X_{T-N})/N$ is called the Simple Moving Average.

c. Double Moving Average

This model combined the linear trend and the moving average. The mathematically expression is

$$x_t = b_1 + b_2 t + e_t$$

where b_1, b_2 are unknown parameters, and $e_t \sim N(0, \sigma_e^2)$. Consider a moving average of the moving average, called double moving average, say $M_T^{[2]}=(M_T+M_{T-1}+---+M_{T-N+1})/N$ or $M_T^{[2]} = M_{T-1}+ (\frac{M_T-M_{T-N}}{N})$

By heuristic development, the estimators of b_1,b_2 are (14)

$$b_1=2M_T-M_T^{[2]}-b_2T$$

$$b_2=\frac{2}{N-1}(M_T-M_T^{[2]})$$

and the estimation of the observation in period T would be

$$X_T=b_1+b_2T=2M_T-M_T^{[2]}$$

The double moving average method may be used to forecast t periods into the future

$$X_{T+t}(T)=X_T+b_2t$$

or
$$X_{T+t}(T)=2M_T-M_T^{[2]}+t(\frac{2}{N-1})(M_T-M_T^{[2]})$$

d. Simple Exponential Smoothing

The function is a horizontal pattern function : $X_t=b+e_t$, where b is an unknown constant and $e_t \sim N(0,\delta_e^2)$. It differs from the moving average method as follows: instead of keeping track of the past N observations, we will keep track of the estimate of b made at the end of the previous period, S(T-1), and the current period's actual demand, X_t. We want to use this information to calculate an updated estimate b(T). A way to obtain the new estimate is to modify the old estimate by some fraction of the forecast error resulting from using the old estimator to forecast demand in the current period. This forecast error is

$$e_1(T)=X_T-S(T-1)$$

where S(T-1) is the smoothed value forecasted one period ago.

So that, if α is the desired fraction, the new estimate of expected demand is

$$S_T=S_{T-1}+\alpha[X_T-S_{T-1}]$$

or

$$S_T=\alpha X_T+(1-\alpha)S_{T-1}$$

The operation defined is called simple exponential smoothing and the fraction α is called the smoothing constant.

Exponential smoothing require a starting value S_0. If historical data are available, then one could use a simple average of the first N observations as S_0:

e. Double Exponential Smoothing

Consider a situation in which the average level of the time series changes over time in a linear fashion. Thus an appropriate model for the time series might be

$$X_t=b_1+b_2\cdot t+e_t$$

where $E(X_t/t)=b_1+b_2t$ and $e_t \backsim N(0,\sigma_e^2)$

If simple exponential smoothing was applied to the observation from linear process of the above equation, we would obtain at the end of period T

$$S_T=\alpha X_T+(1-\alpha)S_{T-1} \qquad (1)$$

Now suppose we apply the exponential smoothing operator to the output of equation (1). This result in

$$S_T^{[2]}=\alpha S_T+(1-\alpha)S_{T-1}^{[2]} \qquad (2)$$

where the notation $S_T^{[2]}$ implies double exponential smoothing, or second order exponential smoothing.

By some mathematical calculation, we could show that the expected demand at period T is

$$X_T=2S_T-S_T^{[2]}$$

To forecast the expected demand of t period in the futures

$$X_{T+t}=(2+\frac{\alpha t}{1-\alpha})S_T-(1+\frac{\alpha t}{1-\alpha})S_T^{[2]}$$

In initiating double smoothing, values must be given to S_0 and $S_0^{[2]}$. Because of their lack of intuitive meaning, it is difficult to assign value directly to these quantities. Usually these initial conditions are obtained from estimates of the two coefficients b_1 and b_2, which may be developed through simple linear regression analysis of the historical data.

<u>f. Multiplicative Seasonal Smoothing (Winters')</u>

This model is $X_t=(b_1+b_2t)\ .\ C_t+e_t,$ where C_t is a multiplicative seasonal factor.

The length of the season is N periods, and the seasonal factors are defined so that they sum to the length of the season, that is

$$\sum_{t=1}^{N} C_t = N$$

To forecast the observation in any future period T+t, we will use

$$X_{T+t}(T)=[b_1(T)+b_2]+b_2(T) \cdot t]C_{T+t}(T+t-N)$$

The development of a forecasting system using Winters' method requires initial value of the parameters $b_1(0)$, $b_2(0)$, and $C_t(0)$ for t=1,2,---N. The historical information, if available, can be used to provide some or all of the initial estimate.

At the end of the current period T, after observing the realization for that period, X_T, we would update the parameter of $b_1(T)$, $b_2(T)$, and $C_T(T)$ as follows:

$$b_1(T)=\alpha\frac{X_T}{C_T(T-N)}+(1-\alpha)[b_1(T-1)+b_2(T-1)]$$

$$b_2(T)=B[b_1(T)-b_1(T-1)]+(1-B)b_2(T-1)$$

$$C_T(T)=r\,\frac{X_T}{b_1(T)}+(1-r)C_T(T-N)$$

g. Additive Seasonal Smoothing

Suppose that a seasonal time series can be described by $X_t=b_1+b_2t+C_t+e_t$, where C_t is the additive seasonal factor. Season length is N period. This model would be appropriate when the amplitude of the seasonal pattern is independent of the average level of the series. In this case

$$\sum_{t=1}^{N} C_t=0$$

We will forecast future value using:

$$X_T+C(T)=b_1(T)+b_2(T)\ .\ t+C_{T+t}(T+t-N)$$

where $b_1(T)=\alpha[X_T-C_T(T-N)]+(1-\alpha)[b_1(T-1)+b_2(T-1)\ ]$

$$b_2(T)=B[b_1(T)-b_1(T-1)]+(1-B)b_2(T-1)$$

$$C_T(T)=r[X_T-b_1(T)]+(1-r)C_T(T-N)$$

Again, the problem require the initial estimates of $b_1(0)$, $b_2(0)$, and $C_t(0)$ for t=1,2,---N. Since the variation is independent of t, the regression assumption is applied. We can estimate $b_1(0)$ and $b_2(0)$ by using a straight line regression. We also could use the fact that $\sum_{t=1}^{T} C_t=0$, and determine the C_t by averaging the regression residuals for each season period.

Our initial estimates (shifting the time constant to current time) will be

$$b_2(0)=b_2$$

$$b_1(0)=b_1+mn\ b_2$$

$$C_t(0)=C_t \quad t=1,2,---n$$

where m is the number of complete seasons of data available (i.e., there are mn observations X_1X_2---, X_{mn}, but only n distinct seasonal factors).

APPENDIX C

FORECASTING ERROR MEASUREMENT METHODS

A. Mean Square Error (MSE).

$$MSE=\sum_{i=1}^{n} (Y_i-\overline{Y}_i)^2/n$$

B. Mean Absolute Percentage Error.

$$MAPE=\sum_{i=1}^{n} |(Y_i-\overline{Y}_i)/Y_i|/n$$

C. Mean Absolute Deviation (MAD)

$$MAD=\sum_{i=1}^{n} |(Y_i-\overline{Y}_i)|/n$$

APPENDIX D

MOVING RANGE TEST

A. The Definition of Moving Range.

$$MR_t = |(\overline{X}_t - X_t) - (\overline{X}_{t-1} - X_{t-1})|$$

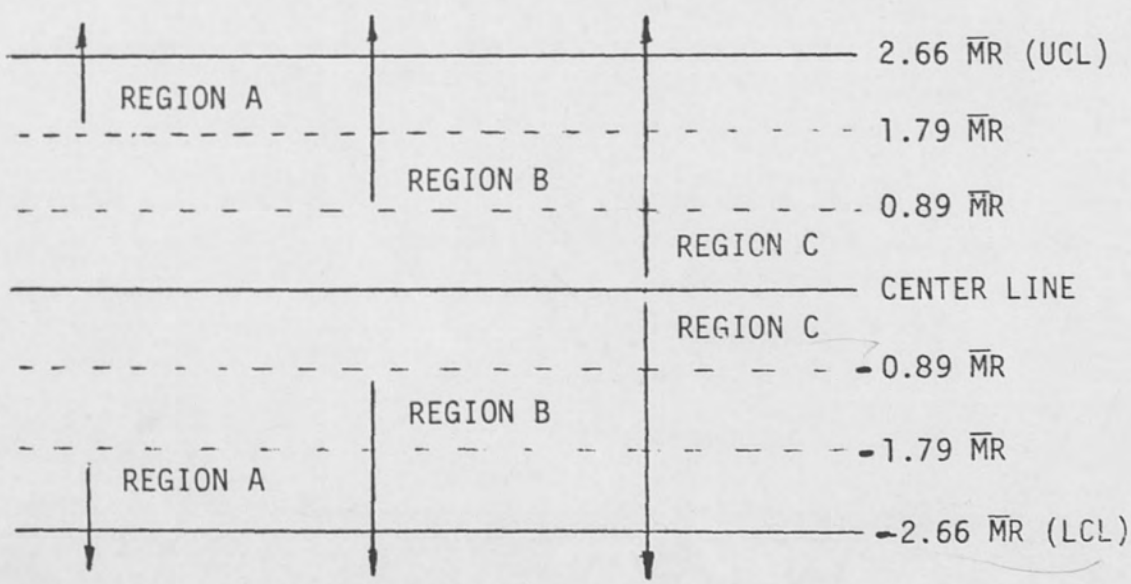
$$\overline{MR}_t = \sum_{t=1}^{n} MR_t/(n-1)$$

where $\overline{X}_t$=Forecasted value for period t.

X_t=Actual value at period t

B. Control Principle.

a. Control Chart (for 99.7% confidence)



The three regions are defined as:

(1) Region A: The region falls outside the line which is away from the center line (suppose it is zero) $\pm$ 1.79 $\overline{MR}$ distance.

(2) Region B: The region falls outside the line which is away from the center line $\pm$ 0.89 $\overline{MR}$ distance.

(3) Region C: The region falls both side of center line.

b. Out of Control Condition.

(1) One point is outside control limit ($\pm$2.66 $\overline{MR}$).

(2) Two out of three successive points are in region A.

(3) Four of the successive points are in region B.

(4) Eight successive points are in region C.

REFERENCES

1. Jess Parrish Memorial Hospital, Titusville, Florida. "Long Range Plan for Health Services and Facilities, 1980-1990." A report prepared by TriBrook Group Inc., 1980.

2. Montgomery, J. Forecasting and Time Series Analysis. New York: McGraw-Hill Book Company, 1976.

3. Kwon, I.; Eickenhorst, K.; and Adams J. "An Approach to Cost Containment: Short-term Patient Census." Hospital Financial Management 10 (November 1980): 38-46.

4. O'Connor, T. J., and Efurd, N. "System Predicts Patient Census, Forecasts Staffing Needs, Costs, Planning." HOSPITAL 52 (March 1978): 95-101.

5. Wood, S. D. "Forecasting Patient Census: Commonalities in Time Series Models." Health Services Research 11 (Summer 1976): 158-165.

6. Harris, R. J., and Adam, E. E. "Forecasting Patient Tray Census for Hospital Food Service." Health Services Research 10 (Winter 1975): 384-393.

7. Swain, R. W.; Kilpatrick, K. E.; and Marsh, J. J. "Implementation of a Model for Census Prediction and Control." Health Service Research 12 (Winter 1977): 380-395.

8. Gutkin, C. E. The Use of a Multiple Regression Model to Predict Hospital Outpatient Visits. U.S. Department of Commerce, National Technical Information Service, HRP-0013137, 1973.

9. Moore, W., and Bock, H. B. Demand Characteristics for Medical Care. NCFHS Research and Development Grant HS00314, Report, Feb. 1973.

10. Gurfield, R. M. "Forecasting Research Requirements for the Hospitalization of Heart Patients." International Journal of Epidemiology 1 (No. 3, 1972): 295-305.

REFERENCES-Continued

11. Bowerman, B. L., and O'Connell, R. T. Time Series and Forecasting: An Applied Approach. N. Scituate, Mass: Duxbury Press, 1979.

12. Sepulveda, J; Sutera, T.; and Atkins, T. "Extensive Forecasting Analysis: A Microcomputer Software Routine." Paper presented at the First International Conference of Computer and Industrial Engineer. Orlando, Florida, March 10-12, 1982.

13. Wheelwright, S. C., and Makridakis, S. FORECASTING METHODS FOR MANAGEMENT New York: Wiley-Interscience Publication, 1973.

14. Thomopoulos, N. T. APPLIED FORECASTING METHODS. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1980.